BBC

QUARK SOUP, DARK MATTER & NUCLEAR PASTA

Just what is going on in this impossible neutron star?

#199 DECEMBER 2021

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

TOUR THE MIDWINTER MILKY WAY

Take in the glittering sights of our home Galaxy as it arches overhead this season

MORNING METEORS

When to watch for a Moon-free Geminid meteor shower

HOW TO REDIRECT AN ASTEROID

The mission to change a space rock's orbit readies for launch

OPTICS UNWRAPPED
Reviewed: Ideal gifts for budding stargazers

WHO LET THE DOGS OUT?
On the origins of canine constellation Canes Venatici

DETAIL IN THE DISCS
Major study sees molecules in planet-forming regions

Welcome

Get to know a different side of the Milky Way this winter

December night skies are long and dark – the ideal conditions for amateur astronomy. Orion's commanding presence is visible from early evenings as the constellation rises, and on **page 54** of this month's Sky Guide, you'll find Steve Tonkin's binocular tour of the Hunter and some intriguing sights within. Many will know of Orion's Belt, now it might be time to discover Orion's Pelt too.

Passing by Orion's left shoulder you'll find the Milky Way, the location of Stuart Atkinson's midwinter tour on **page 28**. Here you'll discover a different side to our Galaxy, not the gaseous nebulae of summer skies – we look out on a different part of the Milky Way in winter – but a host of sparkling star clusters that are a beautiful sight in binoculars and small telescopes. Wrap up warm and go out to find them on the next clear, frosty night – we couldn't help but include the Christmas Tree Cluster at this time of year.

Speaking of Christmas trees, if you're searching for astronomy-related gifts to put under yours, take a look at the Reviews section on **page 86**. Here we look at an affordable, entry-level telescope and a pair of binoculars, and you'll find more ideas in our Gear roundup on **page 96**.

But if the clouds do roll in, or you just fancy keeping warm indoors, we have you covered. Ian Ridpath delves into the history of celestial cartography on **page 62**, investigating the origin of the constellation of Canes Venatici, while on **page 68** Govert Schilling looks at the NASA mission launching soon which will strengthen Earth's defences against asteroid impact: DART is on a collision course with a small space rock to test whether its orbit will be deflected by the impact.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 16 December.

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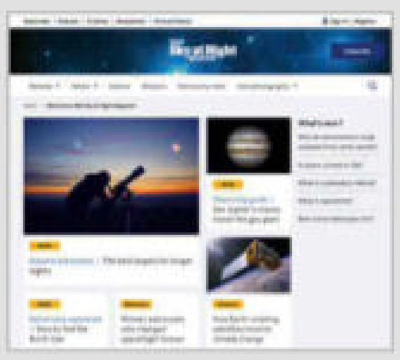
Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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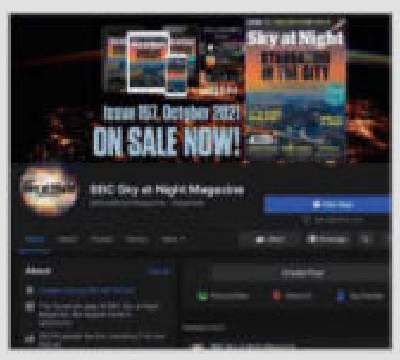

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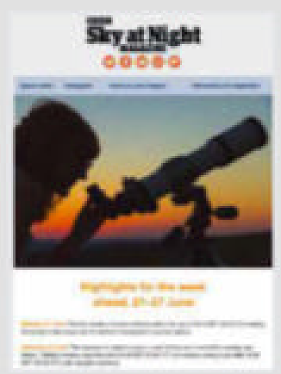

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Find out more at: www.skyatnightmagazine.com

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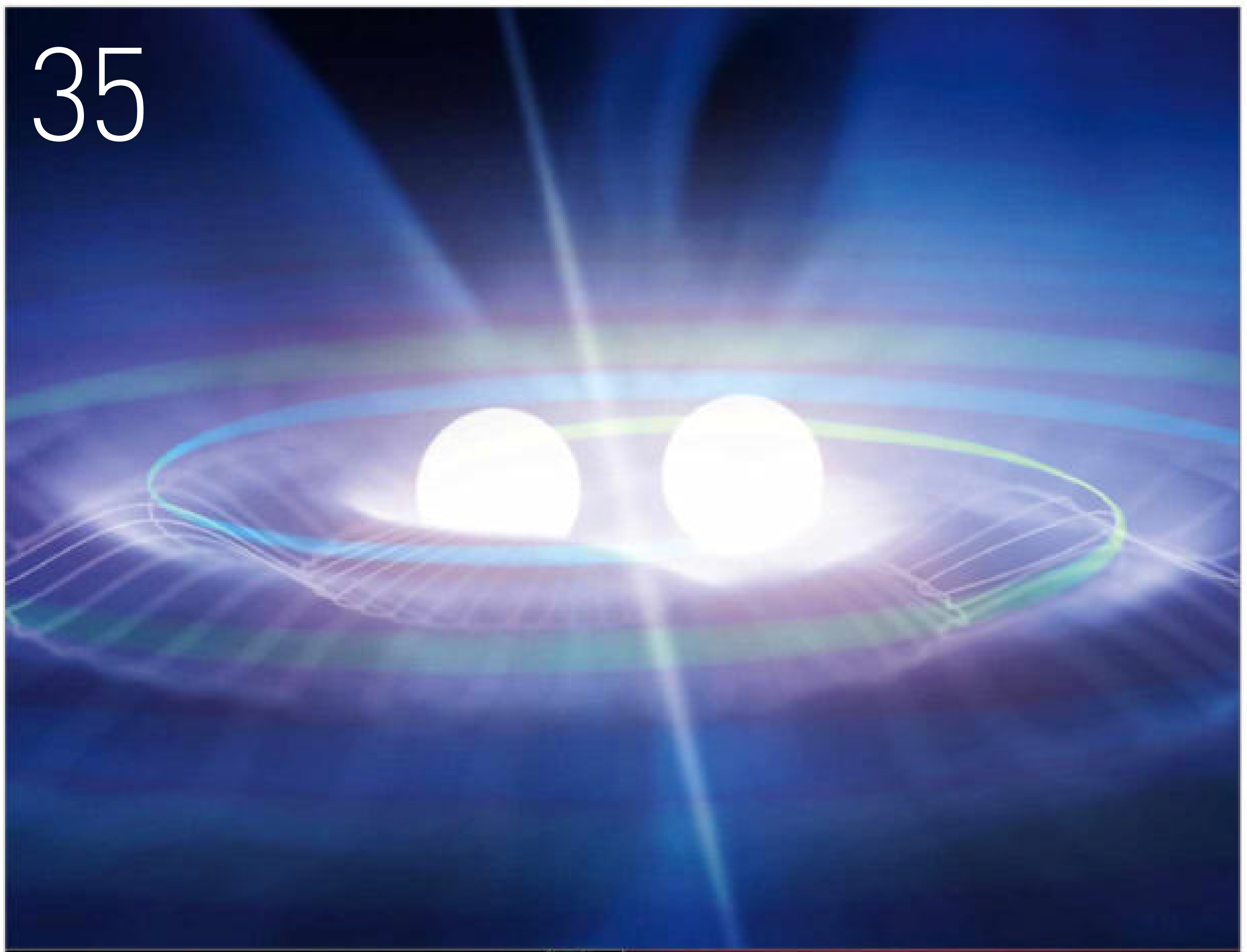
C = on the cover

COVER IMAGE: GRANDFAILURE/ISTOCK/GETTY IMAGES. THIS PAGE: WILL GATER, ANDREY VOLODIN/ ALAMY STOCK PHOTO, NASA/JOHNS HOPKINS APL, @THESHED_PHOTOSTUDIO, PETE LAWRENCE, BBC

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Stuart Atkinson

Astronomy writer

"Many observers think of the Milky Way as a summer spectacle, but there are still plenty of sights to explore and enjoy in it during long midwinter nights." **Stuart guides us around our Galaxy's top targets,** **page 28**

Shaoni Bhattacharya

Science Journalist

"It was fascinating talking to Hannah Susorney and seeing how much we can learn about the internal workings of asteroids from looking at their shapes." **Shaoni meets an asteroid mapper,** **page 98**

Ian Ridpath

Astronomy populariser

"Canes Venatici is small but rewarding to observe this month, yet how did it end up in the sky and who does its brightest star commemorate?" **Ian investigates the mysteries of the constellation,** **page 62**

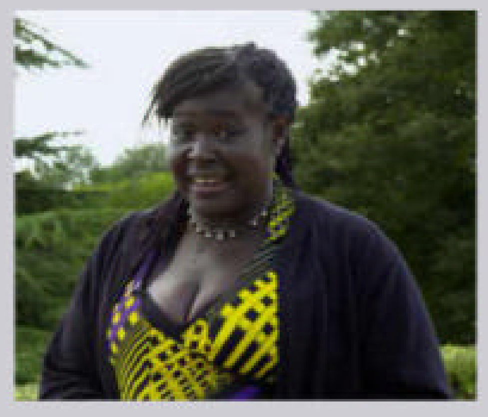
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/AXL4UUW/** to access this month's selection of exclusive Bonus Content

DECEMBER HIGHLIGHTS

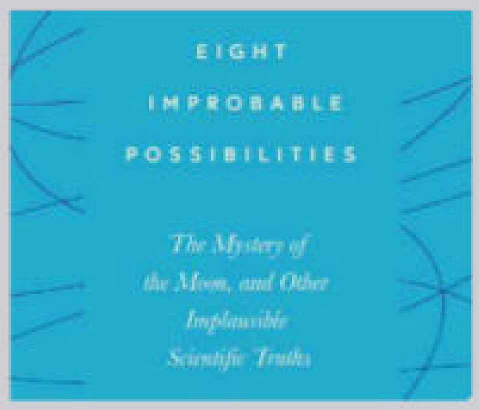
Interview: astronaut Nicole Stott

The former NASA astronaut reveals how life in space made her realise just how precious planet Earth is.



Watch *The Sky at Night: Forgotten Solar System*

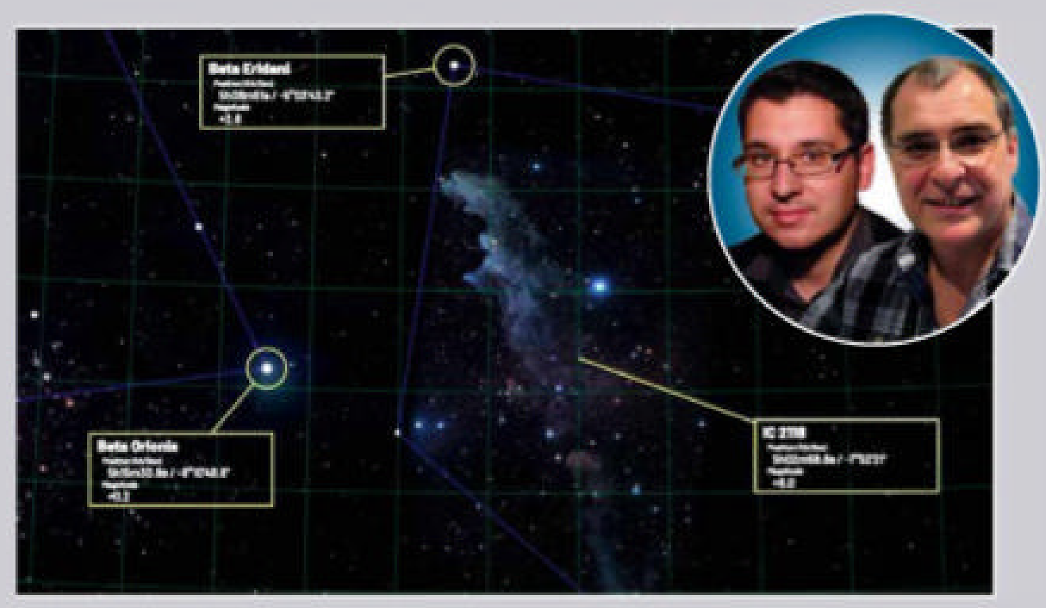
Maggie and Chris reveal why studying the outer planets close-up is vital to our understanding of the Solar System.



Eight Improbable Possibilities

Download and read an extract from science writer John Gribbin's latest book, exploring the mystery of the Moon.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

EYE ON THE SKY

TWIN RING BLING

This beautiful new portrait shows the detail of a barred spiral galaxy with a rare double ring structure

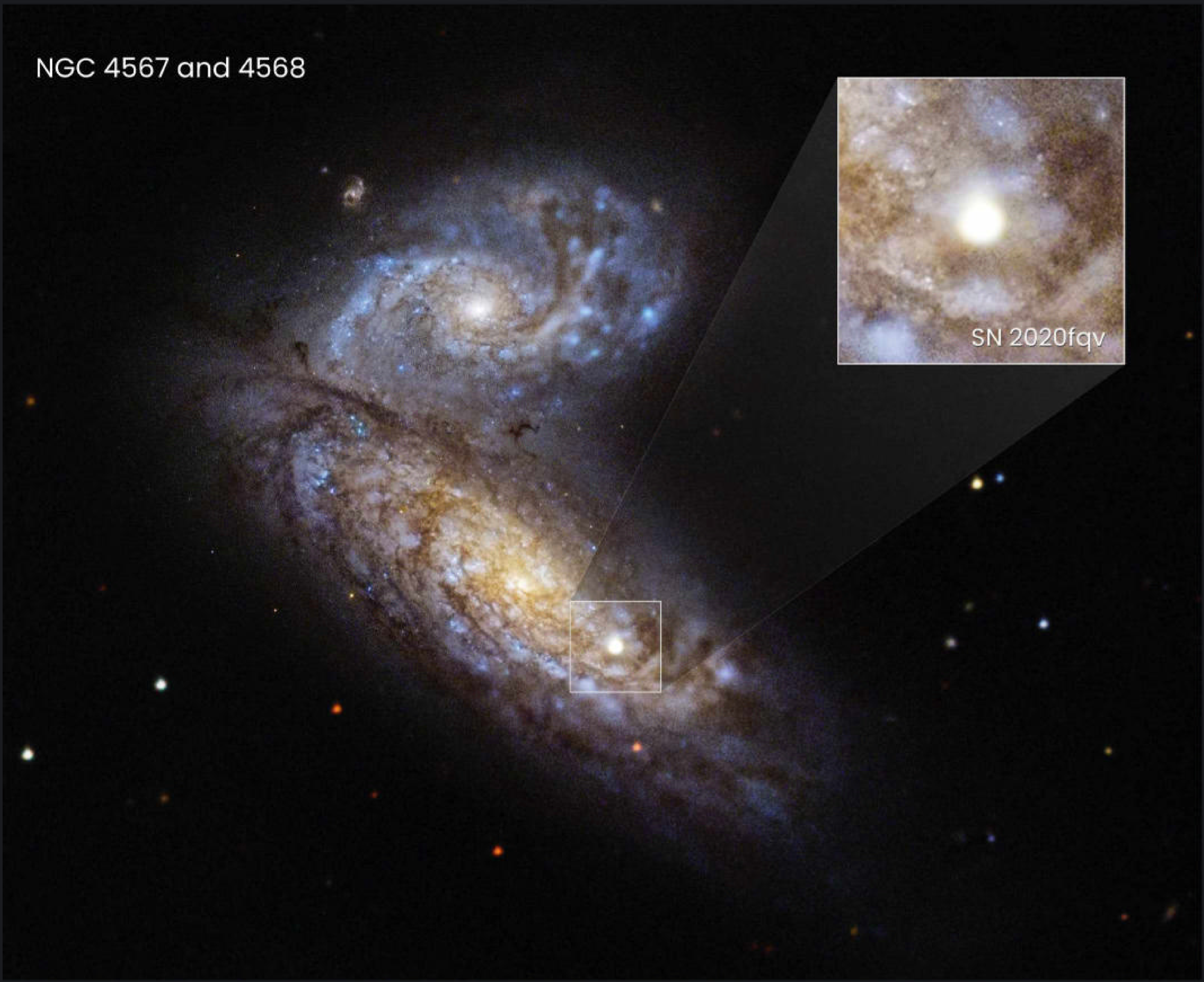
VÍCTOR M BLANCO 4-METRE TELESCOPE, 6 OCTOBER 2021

It was 153 years ago this month that German astronomer Friedrich Winnecke discovered galaxy NGC 1398, a departure from the comets and nebulae that were his usual quarry. Now this new image taken with the DECam, the Dark Energy Camera mounted on northern Chile's Víctor M Blanco Telescope, captures the galaxy in exquisite detail. It's part of the Dark Energy Survey (DES), a project that has mapped 300 million galaxies to shed light on the elusive nature of dark energy.

Sixty-five million lightyears from Earth in the Fornax constellation, at 135,000 lightyears across NGC 1398 is slightly larger than our Milky Way. Unusually it has a double ring appearance, its delicate, feathery spiral arms forming a tightly-wound inner circle bejewelled with stars. Like two-thirds or so of spiral galaxies, NGC 1398 has a central bar of stars, albeit masked by a super-bright core. Despite their ubiquity it's not yet understood how, or even whether, such bars affect a galaxy's form or behavior.

MORE ONLINE
A gallery of these and more stunning space images

DARK ENERGY SURVEY/DOE/FNAL/DECAM/CTIO/NOIRLAB/NSF/AURA IMAGE PROCESSING: T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF'S NOIRLAB), J. MILLER (GEMINI OBSERVATORY/NSF'S NOIRLAB), M. ZAMANI & D. DE MARTIN (NSF'S NOIRLAB)



NASA/ESA/RYAN FOLEY (UC SANTA CRUZ), NRAO/GBO/RAYTHEON/NSF/AUI, ESA/BEPICOLOMBO/MTM, ESO/M. KORNMESSER/VERNAZZA ET AL./MISTRAL ALGORITHM (ONERA/CNRS)

△ In at the death

HUBBLE SPACE TELESCOPE/LICK OBSERVATORY, 21 OCTOBER 2021

For the first time, a star has been witnessed self-destructing in real time. Supernova SN 2020fqv, inside the interacting Butterfly Galaxies NGC 4567 (top) and NGC 4568 (bottom), was watched by multiple ground-based and space telescopes during its explosion. The Hubble Space Telescope even managed to probe the star's ejected circumstellar disc just hours after its demise. Such an unprecedented data haul could shape an 'early warning system' for future supernovae.

◁ New tech gets radar pulses racing

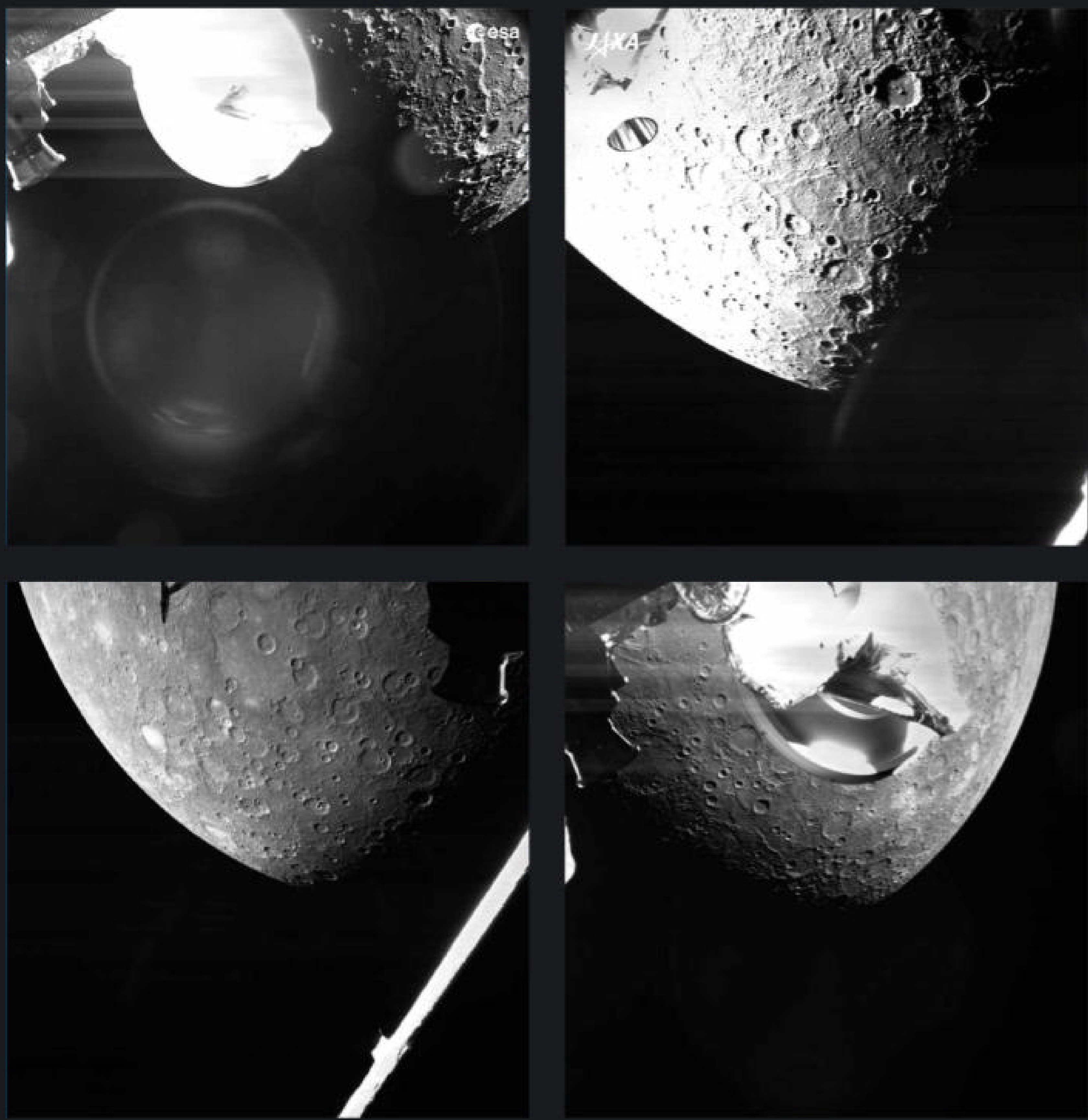
GREEN BANK TELESCOPE, 21 SEPTEMBER 2021

This 1.4-billion-pixel view of Tycho, the massive 86km crater whose bright rays splay out across the Moon's southern highlands, is the highest-resolution image ever taken from the ground using radar technology. Plans are now under way to scale up the project – which uses synthetic aperture radar (SAR) to translate low-powered radar signals into images – by several hundred times in order to capture more distant objects in the Solar System.

I'll be back ▷

BEPICOLOMBO, 1 OCTOBER 2021

Mercury sails into view as European–Japanese BepiColombo makes its first flyby. Having set off in October 2018, the spacecraft skimmed over the planet at an altitude of just 199km, close enough to pick out impact craters and scarps, and to scoop up data about the magnetic and particle environment over the little-explored southern hemisphere. This is the first of six gravity-assisted manoeuvres that will eventually put the craft in a stable orbit around the planet in December 2025.



▽ Asteroid belters

VERY LARGE TELESCOPE, 12 OCTOBER 2021

From giant icy sphere Ceres, 940km in diameter and classed as a dwarf planet, through weirder peanut and dog bone shapes, right down to 90km-wide Urania and Ausonia, these are 42 of the largest objects in the asteroid belt, the doughnut-shaped zone between Mars and Jupiter that swarms with the rocky remnants of our Solar System's creation. For more about how astronomers observe the shapes of asteroids, turn to page 53.


STELLAMIRA
90 ED TRIPLET
TRIPLET APOCHROMAT


STELLAMIRA
90 ED TRIPLET


STELLAMIRA 0.8X Photo

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN

Lucy struggles to spread its solar panels

The asteroid-investigating spacecraft is still generating power as it heads towards Jupiter

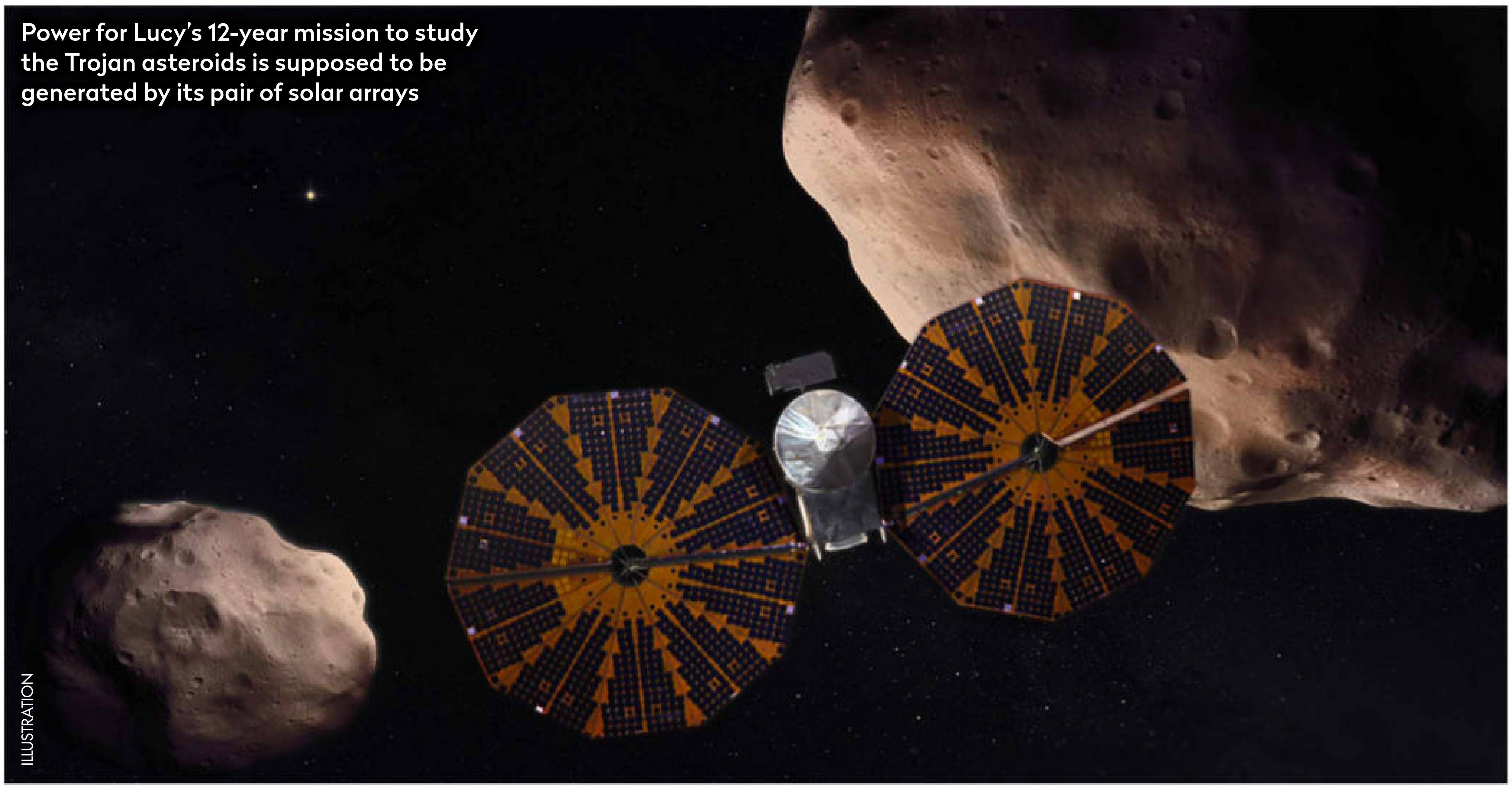
Lucy, the NASA spacecraft that is bound for the two groups of Trojan asteroids on the same solar orbit as Jupiter, has yet to fully open its solar arrays. The spacecraft launched on 16 October at 09:34 UT and reached Earth orbit so precisely that no subsequent manoeuvres were needed. But when the solar panels deployed, 30 minutes later, only one of them unfurled completely and latched into place, while the other remained partially folded.

Even with one 'lame wing', Lucy is generating almost as much power as would be expected if both had deployed successfully. As such, the spacecraft is able to run all the on-board systems needed to begin its journey to the gas giant. As Lucy gets further away from the Sun, however, the solar panels will become less productive, and so NASA is keen to fix the issue.

At the time of writing, NASA was still assessing the situation. As there is no way to visually inspect the spacecraft, the team has to move Lucy into different positions in respect to the Sun and measure how much electrical current the solar panels generate. By doing this they can deduce how far the array deployed before becoming stuck, helping them to understand what went wrong and how they might remedy it.

Lucy is currently flying towards the Trojan asteroids, which are leftover remnants from when the Solar System formed. Over 12 years, the spacecraft will investigate one main-belt asteroid and seven Trojan asteroids, four in the leading 'Greek camp' and three in the trailing 'Trojan swarm'.

http://lucy.swri.edu



Power for Lucy's 12-year mission to study the Trojan asteroids is supposed to be generated by its pair of solar arrays

Comment

by Chris Lintott

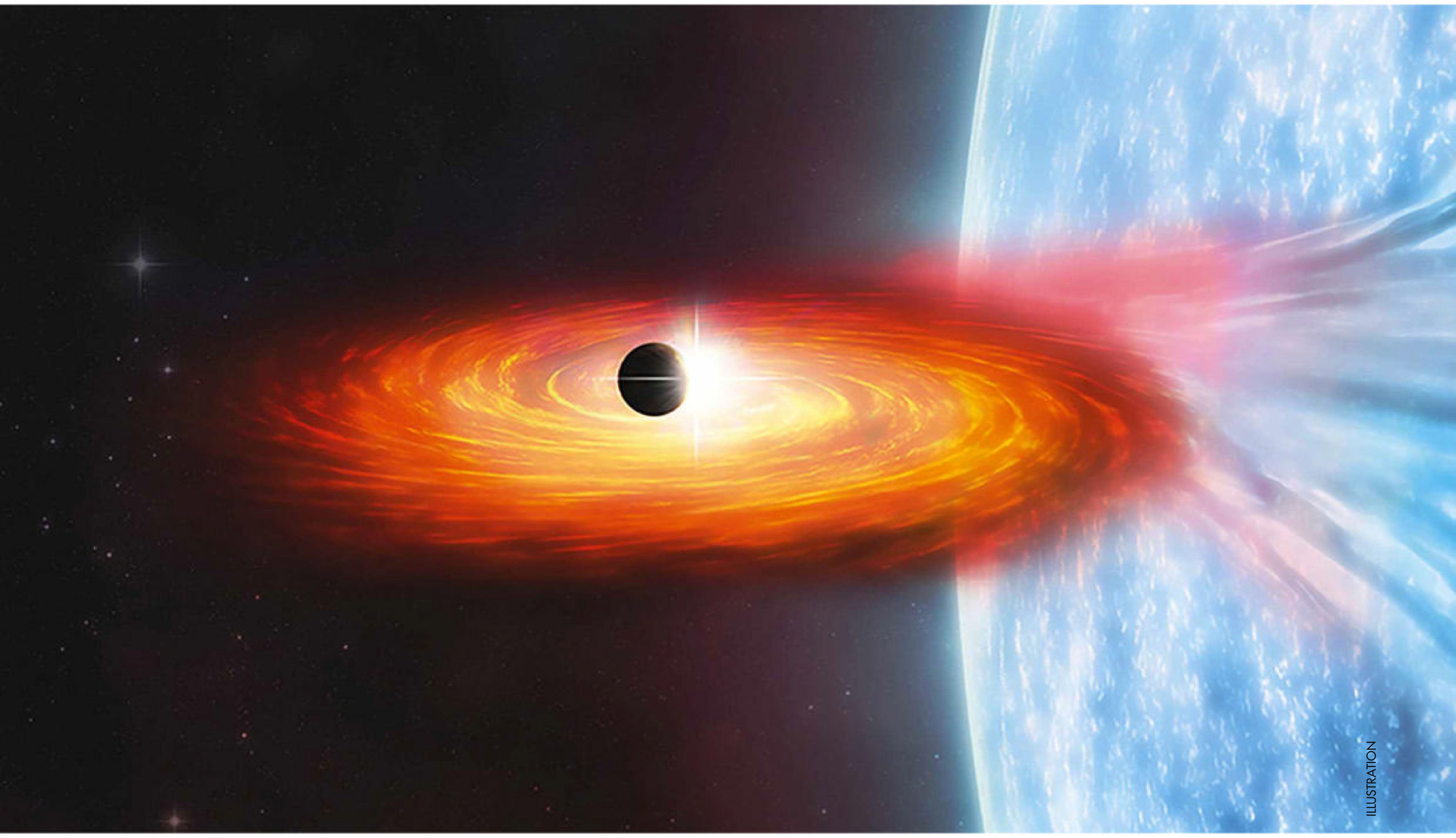
NASA/JPL-CALTECH

NASA's Mission Control now has plenty of time to work out what's wrong with the Lucy mission's recalcitrant solar panels – which have a collecting area of $51m^2$, but even if the probe has to make do with what it has, the fact it is now on its way to the Trojan asteroids should make it a success.

Almost every spacecraft you can think of has had its share of trouble. Galileo had to function without the high gain antenna designed to transmit most of its data back to Earth, and Juno has remained in its parking orbit due to worries about its engines. Spirit kept rebooting its memory when it first landed on Mars, and even the Huygens probe nearly missed out on sending data back from Saturn's moon Titan, due to an error corrected in the nick of time.

All of these glitches are now long forgotten, lost among the wonderful science produced by these plucky spacecraft. I'm sure Lucy will be the same.

Chris Lintott co-presents *The Sky at Night*



▲ A planet passing in front of an X-ray binary star may blink out enough of the star's light to make itself visible from another galaxy

First hints of an extra-galactic planet

The potential planet is thought to be around the size of Saturn

Astronomers may have spotted the first planet in another galaxy. Observations of a stellar system in the Whirlpool Galaxy, M51, have shown what looks to be a planet transiting a star.

As even the nearest galaxies are millions of lightyears from the Milky Way, it's often impossible to distinguish individual stars at visible wavelengths, meaning most techniques currently used to find exoplanets are useless. But at X-ray wavelengths, stars are much dimmer and therefore easier to distinguish. Taking advantage of that, astronomers used ESA's XMM-Newton and NASA's Chandra X-ray Observatory space telescopes to look at a special type of stellar system known as an X-ray binary, in which a star is being consumed by a nearby neutron star or black hole, creating a hot disc of dust that glows brightly in X-rays.

"X-ray binaries may be ideal places to search for planets, because although they are a million times brighter than our Sun, the X-rays come from a very small region," says Rosanne Di Stefano from the Harvard–Smithsonian Center for Astrophysics, who led the study. "The source that we studied is smaller than Jupiter, so a transiting planet could completely block the X-ray binary's light."

The X-ray binary blinked out of sight for a few hours before coming back again, looking unchanged from before the transit. The team considered other possible explanations – such as a passing cloud of gas, another star, or that it might be a variable X-ray binary – but a transiting planet was the best fit for the pattern of fading light seen.

Usually the next step would be to look for at least two more transits, as this is considered necessary to confirm it's a planet. But the dimming pattern suggests the world is orbiting its star at a minimum of 10 times the Earth–Sun distance, so astronomers will have to wait another 70 years for it to transit again. But they are optimistic, nevertheless.

"Now that we have this new method for finding possible planet candidates in other galaxies, our hope is that by looking at all the available X-ray data in the archives, we find many more. In the future, we might even be able to confirm their existence," says Di Stefano.
www.esa.int

NASA/CXC/M. WEISS, CNSA LUNAR EXPLORATION AND SPACE ENGINEERING CENTER, NASA/GODDARD/UNIVERSITY OF ARIZONA, MIT

Chang'e 5 landed on the Moon near Mons Rümker, a volcanic complex in the Oceanus Procellarum

China lunar samples show young lava flows

The samples were returned to Earth in December 2020

The Moon rocks brought back by China's Chang'e 5 sample return mission came from a young lava flow – the youngest ever to be sampled on the lunar surface. Analysis of the rocks has revealed that they are two billion years old, at least a billion years younger than the samples returned by NASA's Apollo missions during the 1960s and early 1970s.

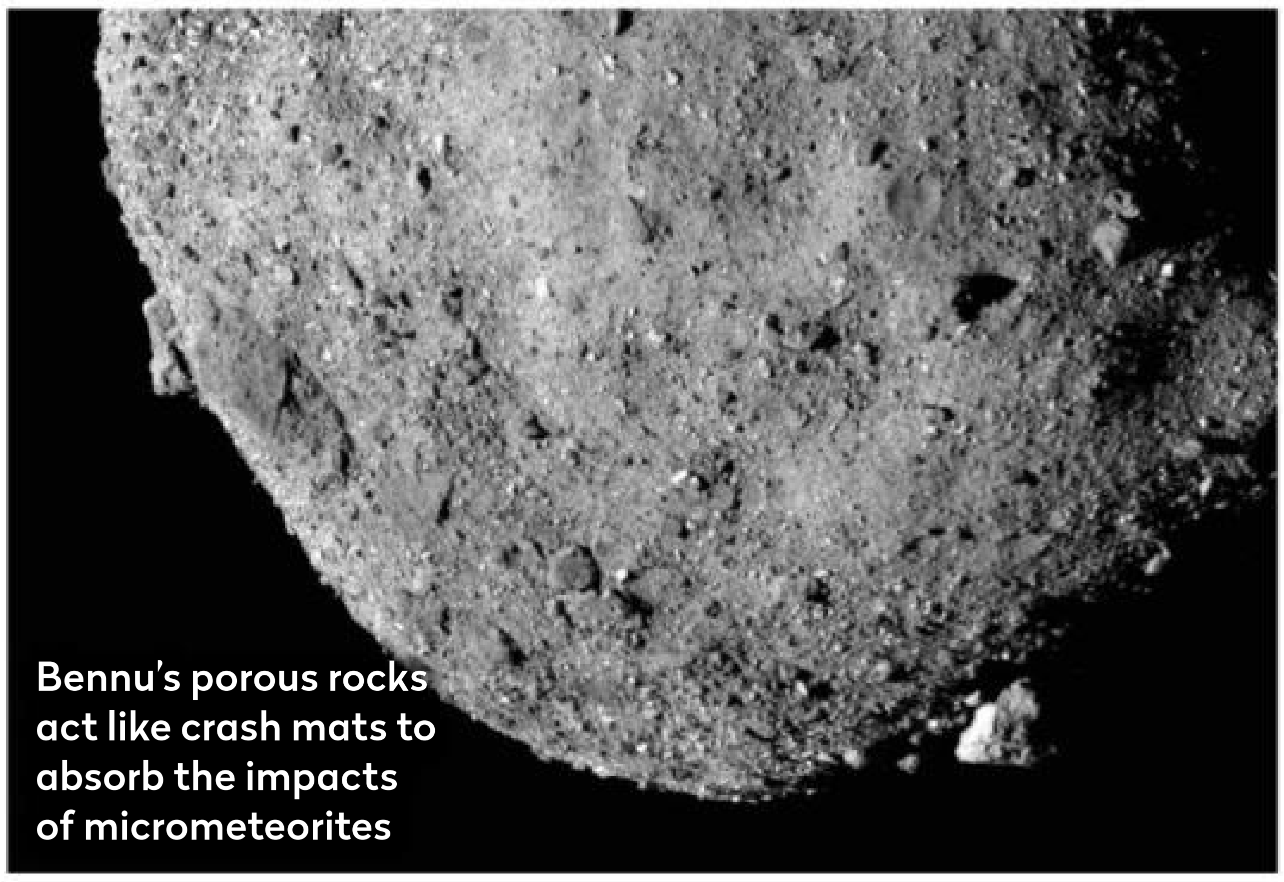
"These young eruption ages are really exciting as it's a complete mystery how the interior of the Moon stayed hot enough to generate such youthful lava flows only two billion years ago," says Dr Romain Tartèse from the University of Manchester, who studied some of the samples.

The landing site of Chang'e 5 was chosen because its terrain appeared to be much younger than other (previously visited) lunar sites, so it would increase the diversity of lunar samples available for study.

Geologists are already getting very excited about samples from the upcoming Chang'e 6 mission, as these will be the first to be returned from the far side of the Moon.
www.cnsa.gov.cn/english

Spongy rocks stop Bennu gathering dust

When NASA's OSIRIS-REx arrived at the asteroid Bennu in 2018, geologists were expecting to find it covered in a layer of smooth dust, known as regolith. Instead the mission found itself above a world of rocks and boulders. Now a new study suggests this rockiness could be down to the asteroid's sponge-like, porous texture.

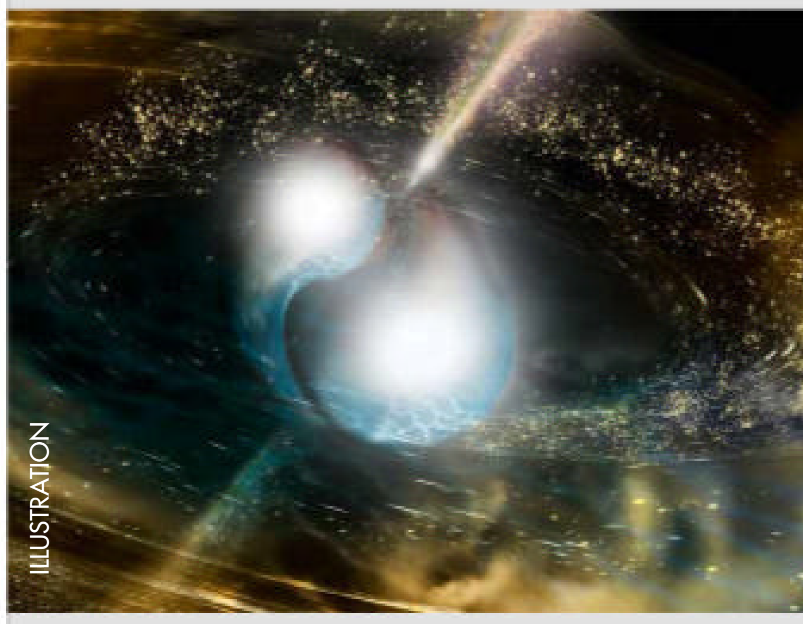


Bennu's porous rocks act like crash mats to absorb the impacts of micrometeorites

To investigate why Bennu has so little regolith, researchers studied infrared emissions from the surface. These showed where the regolith is but also how porous the rocks are, and it seems that the more spongy a rock is, the less likely it is to have dust around it. The investigators think that the porous rocks absorb the impacts of micrometeorites that would otherwise fragment into dust when they hit Bennu.

"Basically, a big part of the energy of the impact goes into crushing the pores, restricting the fragmentation of the rocks and the production of new fine regolith," says Chrysa Avdellidou from the French National Centre for Scientific Research, who helped with the study.
www.asteroidmission.org

NEWS IN BRIEF



Heavy metal factories

New observations of merging neutron stars have found signs of heavy elements being created by the collisions. The source of heavy metals has long been a mystery, as supernovae lack the energy to produce them. But the find shows that neutron stars have been seeding the Universe with them for at least 2.5 billion years.

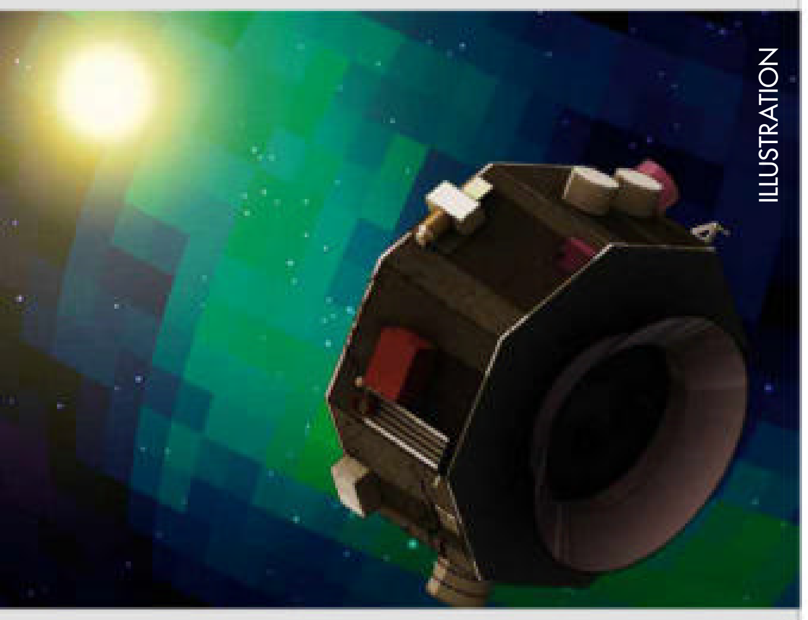
Our Solar System's future

Astronomers have found the first example of a planetary system similar to our own, but with a former Sun-like host star that has already gone through its red giant stage. The planets are far out, suggesting Jupiter and Saturn could survive our star's eventual demise.

Square Kilometre Array host agreement signed

After years of planning, the Square Kilometre Array Organisation (SKAO) has signed agreements with Australia and South Africa to host the telescope. When finished, the Square Kilometre Array will consist of thousands of small radio antennae working as one to create the world's largest radio telescope.

NEWS IN BRIEF



UK to help map solar bubble

The UK has agreed to collaborate with NASA on its upcoming Interstellar Mapping and Acceleration Probe (IMAP) and will build the spacecraft's magnetometer. The mission is scheduled to launch in 2025 and will investigate the magnetic bubble around the Sun to help predict space weather and understand how solar radiation could affect astronauts.

JWST at launch site

After a 16-day ocean voyage, the James Webb Space Telescope (JWST) arrived in French Guiana on 12 October. The spacecraft is scheduled to launch on board an Ariane 5 rocket on 18 December from the ESA's space port in the town of Kourou.

Help search for planets

A new online citizen science project is asking members of the public to help search for new planets outside the Solar System by searching through data from the Planet Hunters' Next-Generation Transit Search (NGTS). Visit **http://ngts.planethunters.org** for more details on how you can help.

NASA, NASA/ESA AND L. HUSTAK (STSCI), NASA

BULLETIN

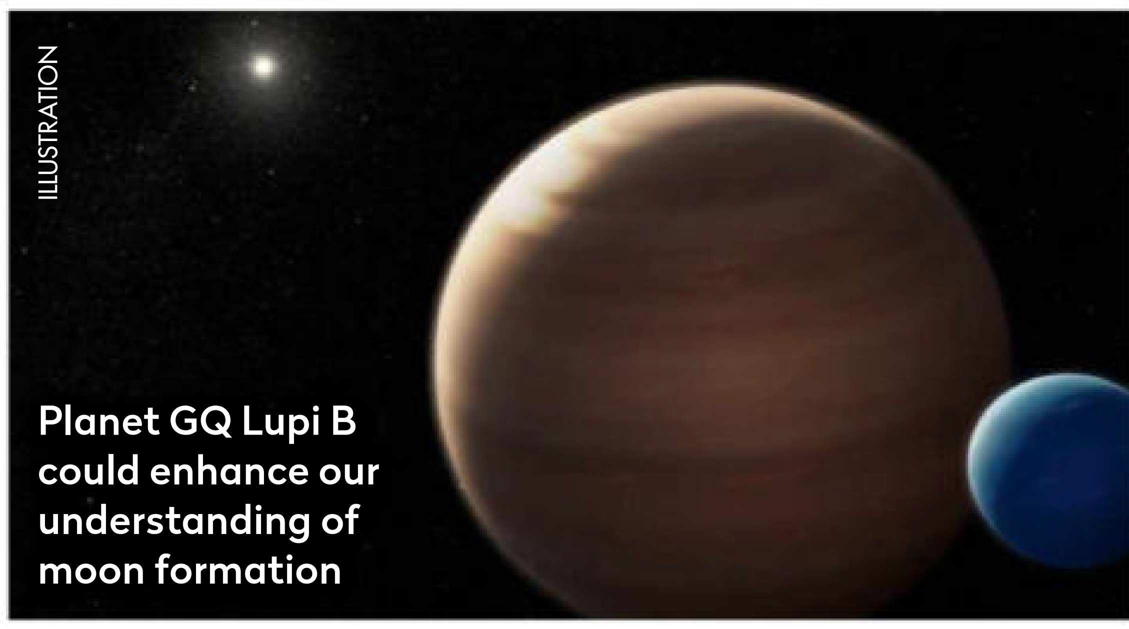
Super-Jupiter's satellite in the making

The young moon could be forming in the planet's dusty disc

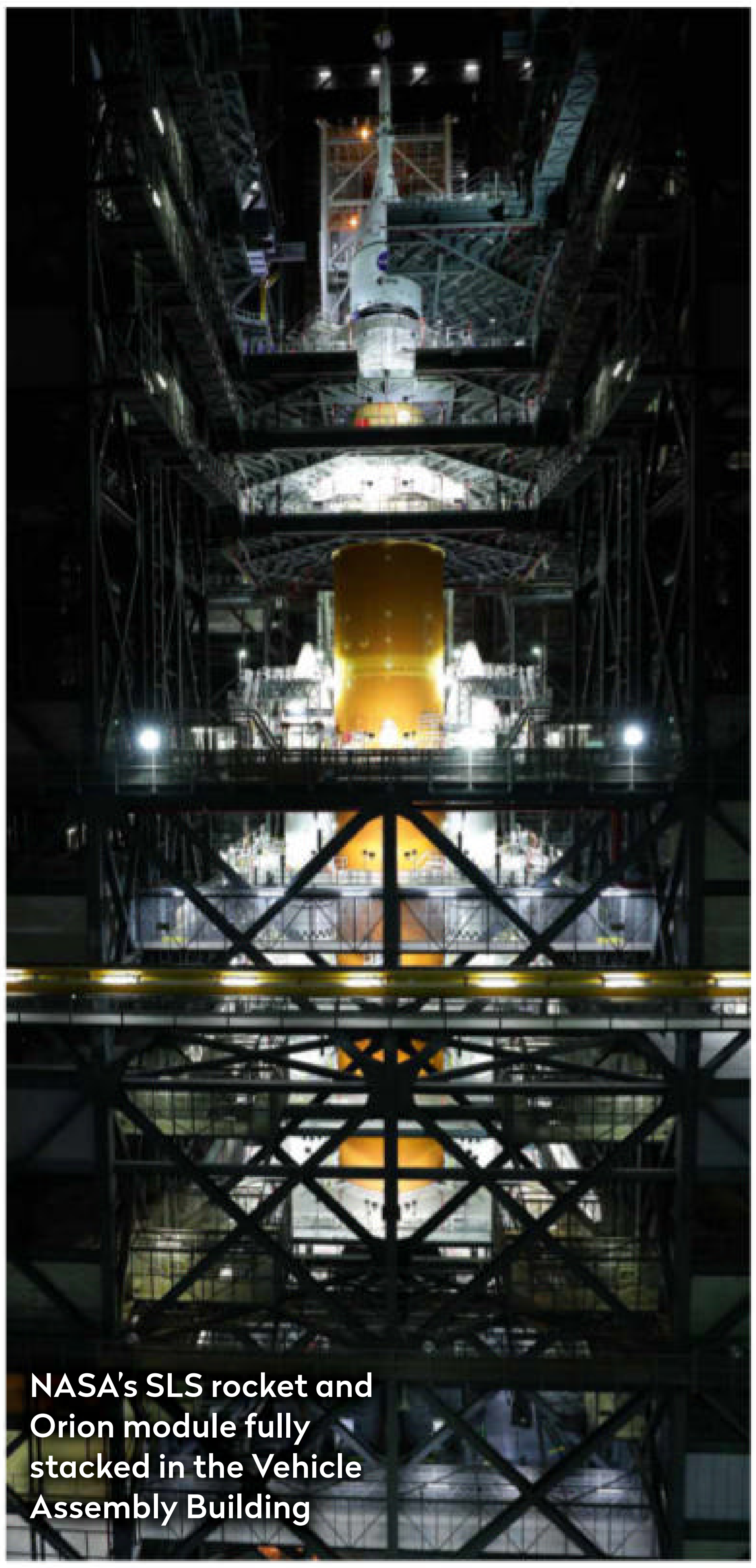
A young super-Jupiter could be cultivating its own set of moons. The planet, called GQ Lupi B, orbits 20 times further from its star than Jupiter does from the Sun, meaning that for the first time astronomers are able to clearly see the ring of dust around it using infrared telescopes.

Observations taken with the European Southern Observatory's NACO infrared camera show the disc is cooler than the planet's atmosphere. This could suggest the disc has a central cavity being cleared out by a growing moon. However to be certain, the team will have to wait for the soon-to-launch James Webb Space Telescope (JWST).

"JWST can take spectra at mid-infrared wavelengths," says Tomas Stolker from Leiden Observatory, who led the research. "In doing so, we could learn much more about the physical and chemical processes in the disc of GQ Lupi B that may enable the formation of moons."
www.eso.org



Planet GQ Lupi B could enhance our understanding of moon formation


NASA's SLS rocket and Orion module fully stacked in the Vehicle Assembly Building

Maiden flight for NASA's Moon rocket set for 2022

The Artemis 1 mission is fully assembled, reviewed and ready to go – but just not this year, as the launch date has been pushed back to February 2022. The spacecraft was moved to the Vehicle Assembly Building on 19 October, and was fully 'stacked' a few days later, meaning all the component parts had been put into their launch configuration.

"The completion of stacking is a really important milestone. It shows that we're in the home stretch towards the mission," says Mike Sarafin, manager of the Artemis 1 mission.

Artemis 1 is the first stage of NASA's endeavour to return humans to the surface of the Moon, as well as a test of the Space Launch System rocket and Orion crew capsule that will take them there. Though the launch was initially scheduled for later this year, it's been pushed back to early 2022 to allow proper time for testing. The next major step is a 'wet dress rehearsal' planned for January, when the core stage is fuelled up and goes through countdown, stopping just short of ignition.
www.nasa.gov

Our experts examine the hottest new research

CUTTING EDGE

Scientists can now map the distribution of molecules in protoplanetary discs, including those that may be important indicators for the presence of life

From organic soup to planets

ALMA reveals fine-grain differences in the chemistry of protoplanetary ingredients

Protoplanetary discs provide the raw materials that planets are assembled from. Within this swirling skirt of dust and gas surrounding a newly forming star, grains collide and coalesce together to create pebbles, which themselves amalgamate into large boulders, then planetesimals, and finally entire, fully grown planets. The exact composition of the local protoplanetary neighbourhood therefore determines the composition of each planet; and is ultimately why, for example, Earth turned out so different from Mars or Neptune.

The problem for scientists who are trying to understand the factors affecting the final outcome of planetary systems is just how much variation there might be in the chemical composition – not only between different protoplanetary discs, but also within the same disc as you move outwards from the central star. However, a huge jump has been made in how to understand these questions now a large partnership of astronomers has used the ALMA (the Atacama Large Millimeter/submillimeter Array) to scrutinise systems in the process of forming planets. ALMA offers high resolution radio observations of the distribution of molecules in protoplanetary discs.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

The results of this ambitious programme are being published as a whole series of 20 separate papers in a special edition of *The Astrophysical Journal.* The study I've picked out here was led by Charles Law, a PhD student in the Harvard and Smithsonian Center for Astrophysics. Law's team created high-resolution maps of the distribution of 18 different compounds within the protoplanetary discs of five newly forming stars. These compounds included carbon-rich compounds such as hydrocarbons like c-C_3H_2, oxygen-rich species like carbon monoxide CO, and molecules containing nitrogen, such as nitriles like HC_3N – some of which are thought to be important in the origins of life. The raw data, collected by ALMA from 2018 to 2019, required a 100 terrabyte hard drive to store it all. Law then began the task of processing and analysing all this interferometer data to generate the separate maps of each different compound.

Different mixes of ingredients

Law's team discovered that the chemicals within the discs are not stirred uniformly throughout – there is a variation in the concentrations of different compounds. His molecular maps showed a diversity of distribution patterns: some compounds were present throughout the disc except for a clear gap, while others existed in concentric rings around the star, and others still were present close to the star but dropped off further out. Such structures within the disc could be due to differences in the dust particles within the disc, or compounds freezing onto the surface of dust grains, or being created or destroyed by ultraviolet radiation from the star.

"What Law and his team have discovered is that the chemicals within protoplanetary discs are not stirred uniformly throughout the discs"

What these maps make abundantly clear is that different planets form in molecular soups with varying ingredients, depending on their location within the disc. This has huge implications for what sorts of planets will form at what distance from their star, and what their composition will be – all factors that will have a profound impact on our ideas of what a planetary system 'should' look like, and how habitable to life they might be.

Lewis Dartnell was reading... *Molecules with ALMA at Planet-forming Scales (MAPS) III: Characteristics of Radial Chemical Substructures* by Charles J Law.
Read it online at: https://arxiv.org/abs/2109.06210

ELEN11/ISTOCK/GETTY IMAGES, DOTTED ZEBRA/ALAMY STOCK PHOTO

Double dipping stars

Could asteroid dust be responsible for a star's periodic dimming?

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

TIC 400799224 is misbehaving. This previously obscure faint star appears in the background of images taken by the planet-hunting Transiting Exoplanet Survey Satellite (TESS) between March and May 2019, and then again in April and May this year. The images show the star dimming, dropping to 20 per cent of its peak brightness in just a few hours before recovering slightly, dimming again, and ending up back where it started two days later.

Since astronomers started monitoring large numbers of stars with the precision required to catch the transit of tiny exoplanets across the face of their parent stars, there have been a steadily increasing number of 'dipping stars'. Kepler, the predecessor of TESS, was particularly useful in spotting them, and was responsible for the identification of the most famous example, Boyajian's Star. This object, first identified by participants in the Planet Hunters citizen science project, showed such dramatic brightness variations that for a while the most plausible explanation was the presence of an 'alien megastructure' around the star.

Further investigations

Follow-up observations soon revealed that intervening dust – not aliens with grand plans – were responsible for the behaviour of Boyajian's Star. In the case of TIC 400799224, there were observations already on hand, thanks to the Evryscope project, which has been scanning the sky nightly since 2017, and ASAS-SN, a survey built to hunt supernovae. These archive observations, plus a targeted follow-up with the global network of telescopes belonging to the Las Cumbres Observatory, also reveal shallower dips that happen frequently, each accounting for a drop of a few per cent in the system's total brightness, as well as a regular cycle of brightening and fading with a period of about 20 days.

So what's going on? So-called 'speckle' imaging, which uses short exposures to capture ultra-sharp images in moments where the air above the observatory is suddenly still, reveals that the system is a binary, with two probably young stars in orbit around each other. The system does shine more brightly than expected in longer-wavelength light, which suggests the presence of dust in the system, and this turns out to be key to the mystery; something is producing substantial amounts of dust which is blocking light from at least one of the two stars.

"The TIC 400799224 system shines more brightly than expected in longer-wavelength light, which suggests the presence of dust in the system"

The researchers have worked out that, given the size of the dips that we see, if an object the size of the largest asteroid in our Solar System, Ceres, was reduced to rubble it would produce enough dust to keep TIC 400799224 dipping for 8,000 years. Rather than invoke such a catastrophic event, however, the team think the most likely scenario involves a large orbiting asteroid that is colliding repeatedly with smaller objects that lie in its way, which produces dust with each collision.

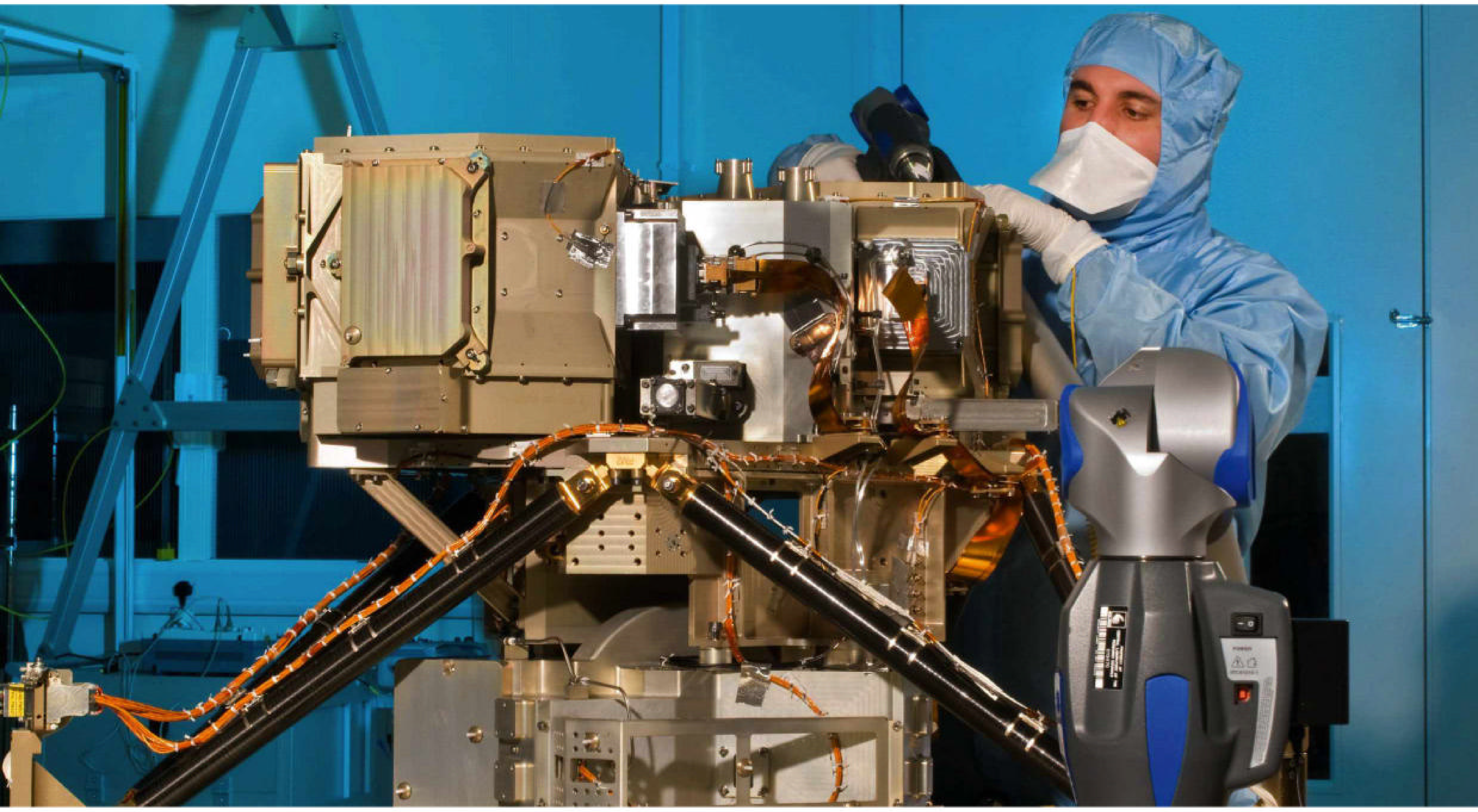
Is that the right explanation? Right now I've no idea – that's why studying these unusual objects is such fun. At a normal magnitude of +12.6, the star is bright enough for back-garden observers to keep an eye on it; whatever is going on around TIC 400799224, more observations from all sorts of telescopes are key to understanding it.

Scientists think they know where the mysterious dust that is obscuring the star TIC 400799224 is coming from

Chris Lintott was reading… *Mysterious Dust-emitting Object Orbiting TIC 400799224* by Brian P Powel. **Read it online at: https://arxiv.org/abs/2110.01019**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



In November's episode of *The Sky at Night*, **Paul Eccleston** looked forward to the long awaited launch of the James Webb Space Telescope

▲ **A total of 12 European countries worked on the JWST's MIRI (Mid Infra-Red Instrument), which will be able to penetrate the dust hiding distant targets to detect things like the formation of planets in detail**

UKRI STFC/RAL SPACE, MDESIGNER125/ISTOCK/GETTY IMAGES

This Christmas, astronomers around the world will be eagerly awaiting more than their presents, as the largest space telescope ever built will be blasted into orbit. The James Webb Space Telescope (often known as the JWST or just Webb) is due to launch this December on an Ariane 5 rocket from French Guiana to the L2 Lagrange point, where the gravitational pull of Earth and the Sun adds together to pull the spacecraft around the Sun in 365 days, keeping pace with Earth. At this stable location, 1.5 million kilometres from Earth, the spacecraft will be able to study the Universe in unprecedented detail.

Conceived in 1989 as the successor to the Hubble Space Telescope (then approaching launch), JWST will take over as the world's flagship space observatory. Its 6.5m diameter primary mirror provides more than seven times the collecting area (and therefore sensitivity) of Hubble. Key scientific aims for the mission include searching for light from the first stars and galaxies (13.2 billion lightyears away), looking at how galaxies form, studying the life cycles of stars, and examining how planetary systems are born.

To answer these fundamental questions about our Universe, Webb will reach out into the infrared (IR) wavelengths on the electromagnetic spectrum as well as visible light. The light from the very earliest galaxies has been red-shifted so far that these stars are best observed in infrared wavelengths.

Additionally, this light passes through dust and gas clouds that surround regions where stars and planets are born, which gives us a unique insight into the factors that drive the diversity of planetary systems we now see. To see the infrared radiation given off by these distant or cool objects, the JWST must itself be cryogenically cooled. To keep the telescope and instruments below –228°C the telescope hides from the Sun and Earth behind a sunshield made of five ultra-thin layers of aluminised foils, each one the size

Paul Eccleston is Chief Engineer at STFC's RAL Space facility. He led the team calibrating the MIRI instrument for the JWST

of a tennis court but less than 1/20th mm thick.

The sheer scale of the telescope and sunshield prevents it being launched fully deployed, so within two weeks after launch a series of mechanisms will unfold it to make the complete spacecraft. With such a complex machine, and no chance of repair once launched, there has been a painstaking and time-consuming process of repeatedly checking everything to make sure all goes as planned. By necessity, this has led to a very long gestation period for the mission in order to minimise the risk of anything going wrong.

JWST is an enormous international effort, led by NASA with contributions from Canada and Europe. The European contribution includes the launch, the Near-InfraRed Spectrometer (NIRSpec) and the Mid-InfraRed Instrument (MIRI). I led the team responsible for MIRI, which captures the longest wavelength of light (5-28 microns). It was built by a consortium of 12 European countries (led from UK ATC in Edinburgh) and the US, with the assembly and calibration conducted at RAL Space in Oxfordshire.

Thousands of us around the world who have collaborated over the past 20 years await the final part of JWST's journey from drawing board into fully operational telescope. The results will surely be fascinating as we open a new window on our Universe.

Looking back: The Sky at Night

9 December 1966

On 9 December 1966 episode of the *Sky at Night*, Patrick Moore looked back at an unexpectedly spectacular astronomical event that had happened the previous month. The 18 November was the peak of the Leonid meteor shower, created by Earth passing through the trail of gravel-sized debris left behind in the wake of Comet 55P/Tempel-Tuttle. Most of the time, the meteor shower is one of the weaker showings of the year, with a zenithal hourly rate (ZHR) of just 10-15 meteors, but once every 33 or so years, it is a completely different story as the parent comet returns to the inner Solar System and refreshes the debris stream.

▲ **The Leonid meteor storm is refreshed by Comet 55P/Tempel-Tuttle every 33 years**

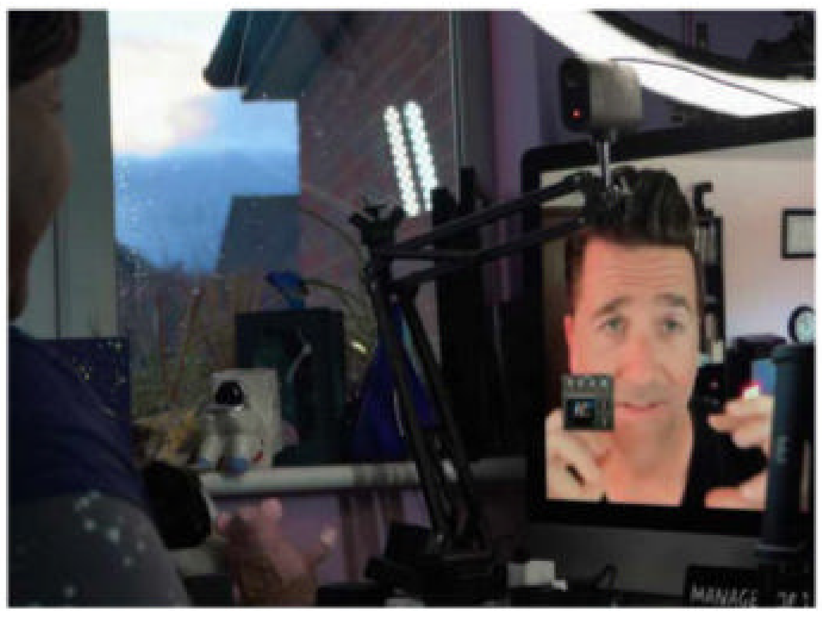
In 1966, the comet had returned, and hopes were high about an impressive showing, at least for North America where it would be night-time when Earth passed through the densest part of the stream. However, the shower was far grander than anyone's expectations, with reports of multiple meteors a minute. The peak rate was recorded at 4:54am at the Kitt Peak National Observatory in Arizona at an astonishing 40 meteors per second (around 144,000 per hour).

The next potential outburst should have been due in the early 2030s, but unfortunately the comet will make a close approach to Jupiter in 2028, throwing off its orbit enough that a repeat showing is unlikely.

Review of the Year

It's been quite a year for astronomy and spaceflight, and once again Maggie, Chris and the rest of *The Sky at Night* team have been at the forefront, bringing the latest space news and stargazing advice to viewers over the past 12 months. This episode the team look back at the year that was, and pick some of their highlights from *The Sky at Night* in 2021.

BBC Four, **12 December**, 10pm (first repeat
BBC Four, **16 December**, 7:30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



▲ **Maggie spoke to NASA's Adam Steltzner in April after Perseverance landed on Mars**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2022* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

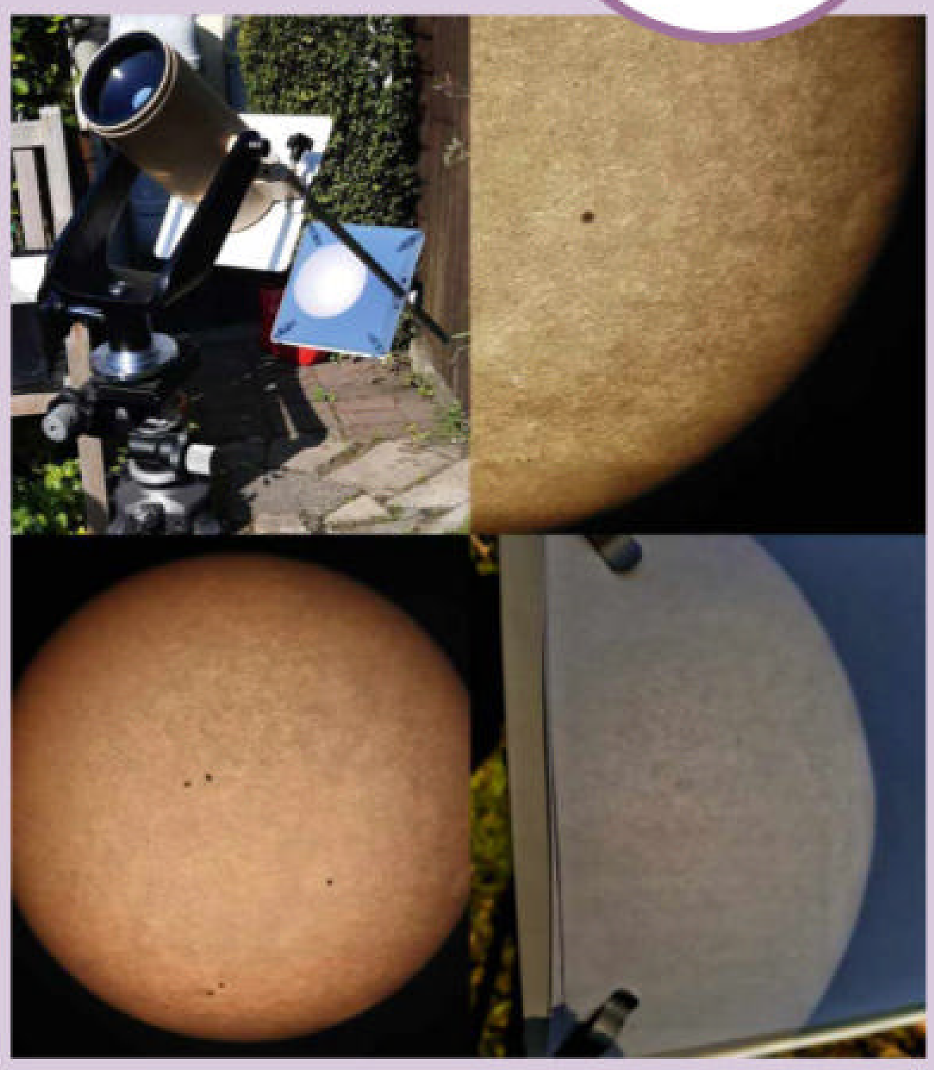
MESSAGE OF THE MONTH

A vintage approach

My solar disc images are fairly mediocre compared to many others I have seen over the years in the magazine, but it's the method of capture that I thought might be of interest. Having a bit of an obsession with vintage optical tubery, I found myself acquiring a nice old telescope with a little history behind it. This tiny Maksutov-Cassegrain was manufactured by PZO in Poland around 1960. If you went to school in East Germany during the Cold War, this is what you had to study with, and it was supplied from new with 50x and 90x eyepieces. If, however, you were schooled in the West, you had a Zeiss Telementor to play with.

That's not to say that the PZO T50 optics are second rate, very far from it. This 70mm Maksutov excels at solar disc projection! I used a smartphone to capture the images projected on paper, and then processed them with 'Snapseed'. You have to get the capture device as perpendicular as possible to the image plate, to avoid distortion and slightly out of focus areas, but it can be done. I am a self-confessed novice when it comes to astrophotography, but I am enjoying the learning journey.

Gary Bivens, Dover

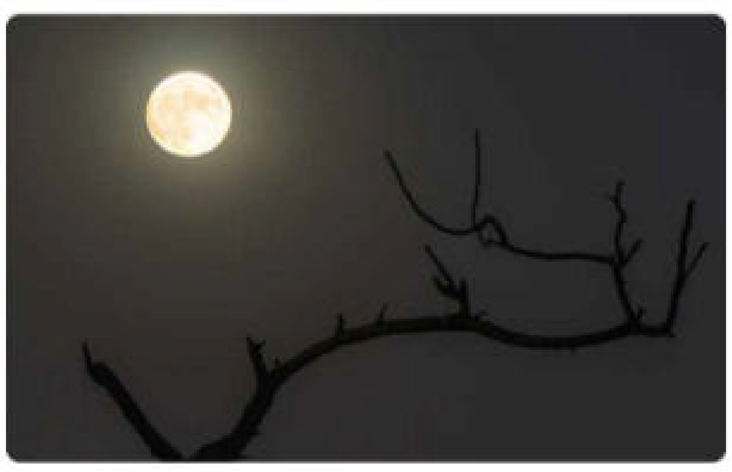


▲ **Gary's images of the projected Sun and his vintage PZO T50 Maksutov-Cassegrain setup**

A delightful story, Gary, and nice sharp sunspots in images with a great artistic quality from the paper grain! Compound scopes like Maksutovs aren't best for solar projection – the folded light path increases heat build-up – but your PZO looks like it's all metal and without plastic parts that could melt in focused sunlight. **– *Ed.***

Tweet

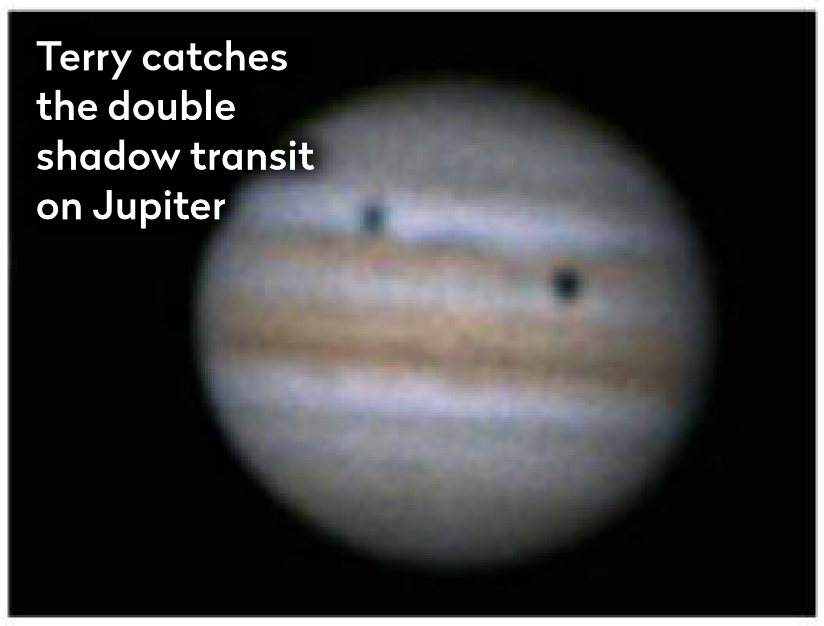
Mehmet Karagül
@mehmetkaraguel • 24 Oct
Including a deer in this photo of a Hunter's Moon on 20 October 2021 would be perfect, but all I have is a dry tree branch that looks a bit like deer antlers.
#HuntersMoon #FullMoon



Puzzling solution

The grid-like pattern on Paul Mitchell's photograph of the Moon ('Interactive', October 2021 issue, 'Lunar puzzle', page 21; see above) is likely to be a picture of the camera's CCD, caused by the light entering the camera due to what's known as 'total internal reflection'. This is defined as the optical phenomenon in which waves arriving at the interface from one medium to another are not refracted into the second medium, but completely reflected back into the first medium.

Stuart Hunter, via email



Terry catches the double shadow transit on Jupiter

Seeing double

As a newbie to astrophotography, I was pleased to get a picture of the Jupiter double moon shadow transit on 4 October that was highlighted in the October issue ('Sky Guide', page 46). At around 8:40pm

the clouds parted and I shot two 1,000 frame AVI videos with my Celestron NexStar Evolution 9.25 telescope and Skyris 236C colour CCD camera with an ultraviolet/infrared filter.

During the second of these transits, the clouds closed in and the view was lost. But I could see in the thumbnails on my laptop that there were two black specks, telling me that I'd captured the moon shadows.

The final pictures were processed with iCap 2.4, AutoStakkert!, RegiStax and Affinity Photo; they may not be of the standard of your always excellent contributors, but they are pleasing to me nonetheless.

Terry Slattery, Notts

Enjoy the view

Thanks to Kevin Thompson from Knighton, Powys, for sending in his design for the TOMO Astro Chair Mk1 (above). In terms of usefulness and comfort, it's a winner, Kevin!

Ergonomically designed in the best tradition of Heath Robinson and Rowland Emett, it assures a pain-free view of the stars, with everything that might be needed in a position to eliminate the need for a reclined observer to lift their gaze from the eyepiece. We hope a Mk2 is forthcoming, and might include ingeniously powered motor drives for the altitude and azimuth actuator wheels, which move telescope and observer as one. ***– Ed.***

ON FACEBOOK

WE ASKED: Real or imaginary, what do you want for Christmas this year?

David Mottershead A cloud zapper!

Joe Padfield A chainsaw to cut the neighbours' trees down so I can see the southern horizon!

Peter Turvey A 6-inch Cooke refractor.

Anne-Marie Hinks Benstead A year of clear skies!

Steve Green Why wait? Get it now! An observatory at the bottom of the garden.

Henry Shaw I would like my whole telescope shopping list, but that's a very big list.

Gerry Lecount A good quality high-magnitude spotting scope.

Jonathan Brown Meteor samples.

Carol Miller An eVscope. I have ongoing eye problems, one of which is beginning to curtail my viewing through a regular telescope, so seeing the Unistellar eVscope eQuinox featured in *Sky At Night Magazine* ('First Light', September issue, page 86) brought hope to a future of continued sky-watching. I hope to have one in 2023 when I reach my 60th birthday!

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Sky-Watcher 200P Dobsonian telescope that appears to have mildew or mould on the primary mirror. Is this a big problem and should I clean the mirror?

SAMUEL PARRY

▲ Use one piece of cotton wool at a time to clean the mirror

Cleaning a Newtonian reflector's mirror should only be carried out if it is absolutely necessary. However, mildew and mould can damage the surface through chemical reactions so if you suspect their presence, cleaning the mirror correctly would be a good idea. This should never be done with a cloth but with the gentle action of water.

Start by carefully removing the mirror from its mounting cell and place it in a plastic bowl full of tepid water and two drops of mild detergent. Leave to soak for five minutes and rinse under tepid running water. Refill the bowl with fresh tepid water and another two drops of detergent then soak a piece of cotton wool in the water and drag it, under its own weight only, across the mirror once and discard. Repeat with several more pieces of cotton wool until the whole surface has been cleaned. Pour distilled water over the mirror and place it on its side on a towel until it is dry then re-install and collimate.

Steve's top tip

What is a finderscope?

Finding celestial objects through a telescope eyepiece can be harder than you might imagine as the small field of view and magnification of the instrument makes it easy to miss a target. A finderscope is a small telescope that attaches to the main observing telescope and is aligned with it. A finderscope's short focal length typically gives a wide field of view, perfect for star-hopping to the object you seek by observing through it to get you most of the way there. Final pointing is then carried out using a long focal length eyepiece in the observing scope, locating the object ready for observing.

STEVE RICHARDS

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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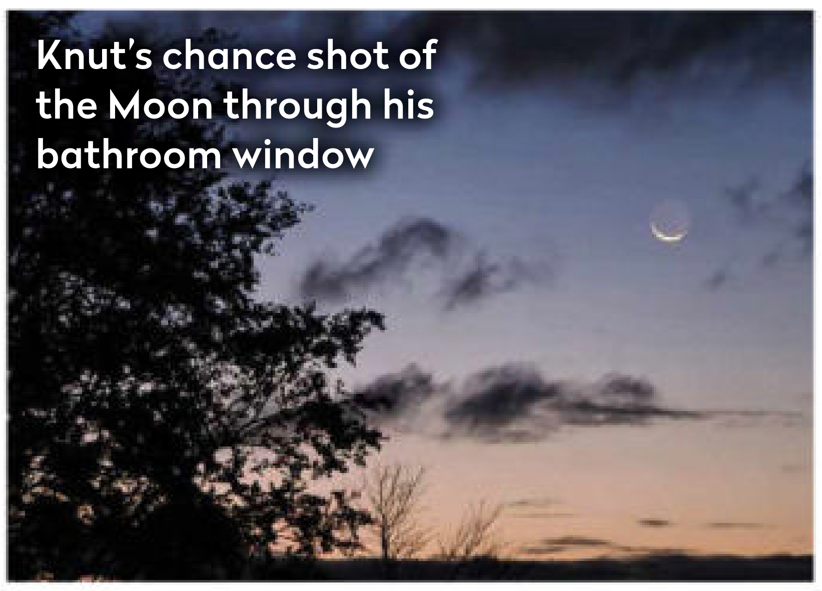


Knut's chance shot of the Moon through his bathroom window

Morning Moon

▸ I used the early pandemic days to try my hand at astrophotography, purchasing a half-decent DSLR and a Samyang 135mm lens. I set about viewing a multitude of YouTube videos on how to take untracked images of deep-sky objects, then stack and post-process them.

A year later I've added some kit, including a star tracker, but I've also noticed a distinct lack of clear-sky opportunities this year compared with last! However, while brushing my teeth on the morning of 5 October, I was confronted with a fantastic view of the Moon through a Velux window.

I grabbed my smartphone in the hope of capturing a half decent image. Two shots later – plus some minor tweaks in Photoshop Express on my phone – and the result (above) didn't seem half bad.

Knut Beekmann, via email

Instagram

cellistontheroof • 20 October

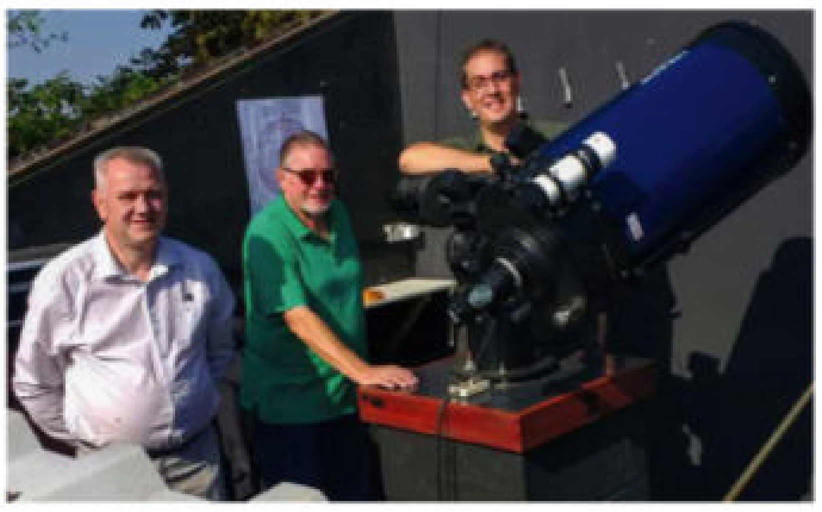
A quick capture of Jupiter from Sunday evening, while I was prepping for trying to capture Uranus. I assembled the imaging train and noticed that the Great Red Spot was just about to leave our sight, so I took a quick two-minute exposure. Seeing was poor but *c'est l'astronomie* down here! Always happy to see the cluster of white storms in the southern hemisphere! @bbcskyatnightmag @astronomypicturesdaily @astronomy.magazine @astronomyinsider

SOCIETY IN FOCUS

Letchworth and District Astronomical Society (LDAS) has been 'looking up' from Hertfordshire for over 35 years. Founded in 1985 in Stevenage, we took our new name in 1991 when Letchworth, the first Garden City, offered us a site for our observatory at Standalone Farm.

We are a family-based society where everyone is invited to join in our activities. Our main meeting occurs on the last Wednesday of the month, when we normally have a guest speaker, a chat and a roundup of news and objects of interest to observe in the coming month. Recent speakers have talked about dark skies, binocular astronomy, NASA's Dawn mission and giant elliptical galaxies, delivered in our annual lecture by new honorary president Dr Matt Boswell of the Cambridge Institute of Astronomy.

During lockdown we missed our star parties and workshops, but we managed to run two telescope workshops online and also got in some live online solar observing



BOB BALDWIN

▲ **David Brassington, Robin Brough and Grant Bowskill with the society's 14-inch Meade LX200 telescope on an EQ8 mount**

from a member's observatory. In August 2021 we held a picnic, and a clear sky in September allowed us to enjoy an informal pop-up planetary observing evening. The re-silvered mirror of one of our hire scopes saw first light and gave us excellent views.

Looking ahead, we have a project underway to improve access to our observatory and also to improve the view to the southwest sky by pruning the hedge that has grown while we have been away.

Mike Eltringham, Committee member, LDAS
▸ **www.ldas.org.uk**

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

Radio Elon Musk: The Evening Rocket

BBC Radio 4, available online

Harvard historian Jill Lepore's five-part radio series explores what helped shape the SpaceX founder and would-be Mars coloniser Elon Musk. **bbc.in/3GmR1m4**

Online James Webb Space Telescope

10 December, 7:30pm

All are welcome to Norwich Astronomical Society's online talk on the largest space telescope ever launched, the James Webb Space Telescope. Book your place at: **www.norwichastro.org.uk**

Live Geminids stargazing

Bellingham campsite, Northumberland, 12 and 13 December

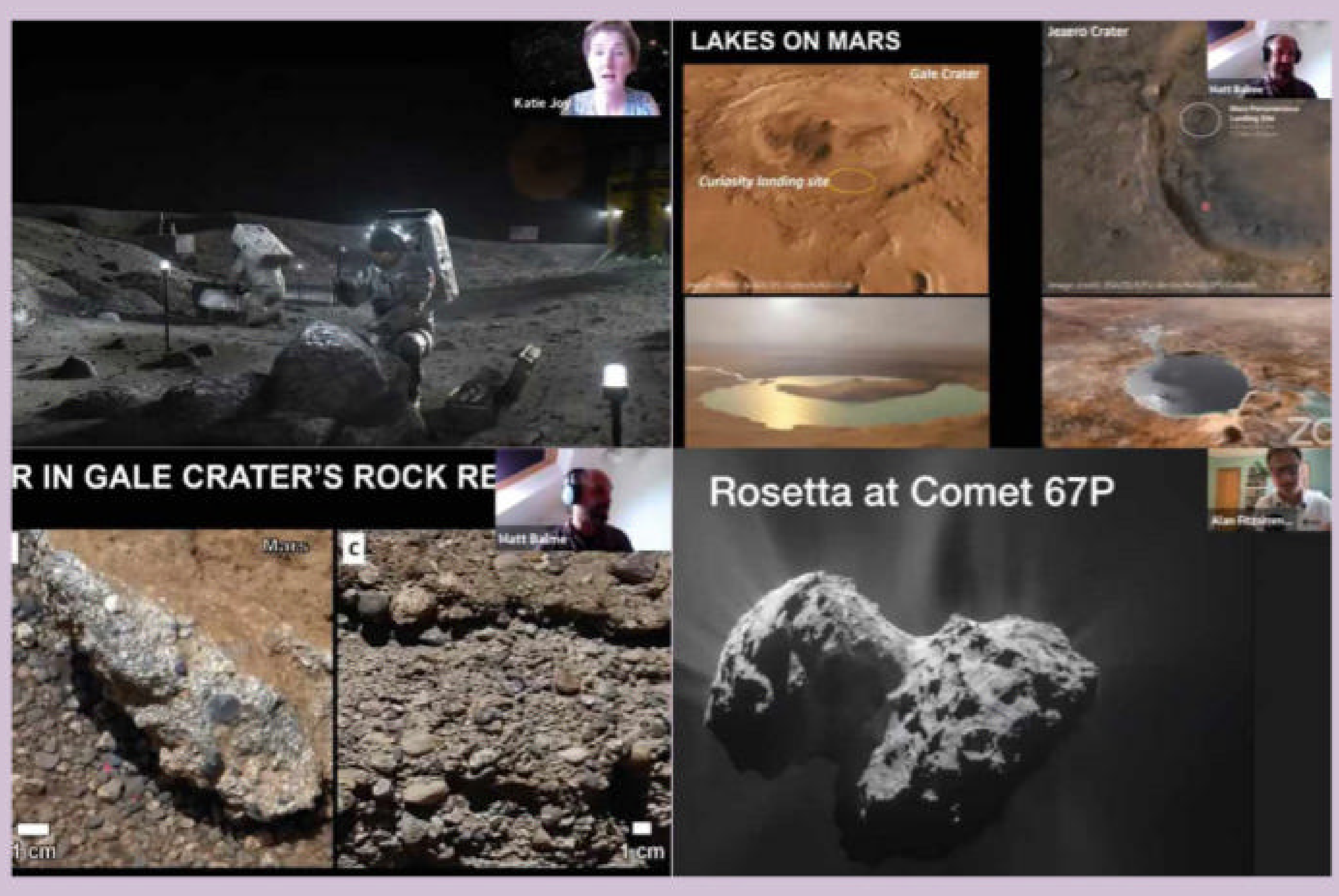
Enjoy an evening of dark-sky stargazing, and possibly a few Geminids meteors, with host astronomer Robert Ince and friends. Tickets £15. **www.stargazingevents.com**

Live Time in Einstein's Universe

Christ Church, Redford Way, Uxbridge, 13 December, 8pm

What happens to time inside a black hole? Does time even really exist? West of London Astronomical Society welcomes potential new members to a fascinating talk by best-selling author Colin Stuart. Free. **www.wolas.org.uk/meetings**

PICK OF THE MONTH



▲ Experts explain what we can learn from the features of Mars, the Moon, comets and more

Online Year of Space lecture series

Enjoy the Geological Society's talks from a range of space and planetary scientists

The geology of the planets, moons and smaller bodies in our Solar System (as well as the worlds beyond) has been the focus of the Geological Society's '2021 Year of Space'. Now you can catch up with all 10 of its public lectures, including a tour of the landscapes of Venus with Dr Peter Grindrod of the Natural History Museum and a close-up look at asteroids and comets with Professor Alan Fitzsimmons. In other talks, Dr Katie Joy explores the surface of the Moon, and Dr Ralph Lorenz (from the John Hopkins University Applied Physics Laboratory) delves into Saturn's icy moon Titan. For details see: **www.geolsoc.org.uk/space21/lectures**

Online Planetary magnetic fields

16 December, 7:30pm

The Astronomical Society of Glasgow presents 'A Tour of Planetary Magnetic Fields in the 21st Century', a Zoom lecture by Dr Ciaran Beggan from the British Geological Survey's Lyell Centre. See **www.theasg.org.uk** for login details.

Live Observation evening

Toothill Observatory, Southampton, 29 December, 7:30pm

Join Solent Amateur Astronomers for an evening observing the Andromeda Galaxy, Orion Nebula, Uranus, Neptune and more, weather permitting. Non-members: adults £5, children 50p. The club also hosts Bob Mizon's talk 'Comets in History' on 14 December, via Zoom. See **www.solentastro.org** for more.

Live Keele Observatory

Tuesdays and Saturdays

Keele Observatory is starting to welcome back visitors. Entry is free, but it is booking only: e-mail **astro.obs@keele.ac.uk** with your name and the total number of people.


UNISTELLAR
THE UNIVERSE AWAITS
M42 - NEBULA IN ORION
M51 - WHIRPOOL GALAXY
M57 - RING NEBULA
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Nikon EYEPIECE TECHNOLOGY
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FIELD OF VIEW

Space mission mishaps

Slip-ups can happen anywhere, including space, as **Jonathan Powell** discovers

ALEXANDER WELLS/FOLIO

Science fiction may have informed us in 1979 via *Alien* that "In space no one can hear you scream", but the verbal anguish from control centres here on Earth when space missions go wrong has at times been all too loud and clear.

Take the Hubble Space Telescope. It was soon apparent after the $1.5 billion instrument was deployed in April 1990 that something was awry: the long-awaited crystal-clear views of the heavens looked worryingly blurry. Instead of a sequence of glorious pictures, Hubble squinted hopelessly into the distance. But a 1993 spacewalk corrected the mirror's flaw, just 1/50th the thickness of a human hair, and the telescope has exceeded expectations ever since.

Mars isn't called the graveyard of spacecraft for nothing, but the cause of one mission failure must have been particularly hard to bear. Designed to study the planet from orbit and provide a communications relay, NASA's Mars Climate Orbiter instead met a fiery death in the Martian atmosphere in September 1999. It was later found that the $125 million craft was sent off course by a misunderstanding between the team at the Jet Propulsion Laboratory, who used metric measurements in their calculations, and the team at Lockheed Martin Astronautics in Denver, who built the orbiter using imperial inches and feet.

In what was to have been a triumph for the European Space Agency (ESA), Beagle 2 was despatched to Mars with a touchdown date of 25 December 2003. However, there was no Christmas Day greeting from the Red Planet, just an ominous silence. ESA eventually learned what had become of Beagle 2 in January 2015, after images of it on the Martian surface revealed that it had touched down but hadn't deployed all its solar panels. Without enough power, poor Beagle couldn't even muster a lonely howl from the dusty surface.

Humanity's orbiting outpost, the International Space Station (ISS), hasn't been immune from mishap either. Who can forget the tool bag that drifted slowly away from a spacewalking astronaut's desperate grasp in November 2008. A decade later, in August 2018, the crew, alerted to a sudden drop in cabin pressure, discovered a tiny 2mm hole in the Russian Soyuz module that was docked with the ISS. Said to be caused by a drill slip during a repair job on Earth, it was patched up with epoxy and tape.

More recently, the arrival of the Nauka module at the ISS sent it into a spin, literally. Almost 15 years late for its first planned launch, when the Roscosmos (Russian space agency) lab docked in July 2021, an unplanned burn of its engines caused the whole ISS to rotate one and a half times before the fuel ran out.

However, like the great, perilous sea voyages of maritime history, when the prospect of a tall ship arriving at a distant shore instilled a spirit of adventure, that same spirit continues with those who are expanding the frontiers of human exploration today. Despite the mishaps, in 2021 three nations sent scientific craft safely to Mars, and with successful launches, SpaceX, Blue Origin and Virgin Galactic between them have begun a new era of civilian spaceflight.

Jonathan Powell is a freelance writer and broadcaster. A former correspondent at BBC Radio Wales, he is currently astronomy columnist at the *South Wales Argus*

◄ **Let Orion be your guide, as the winter delights of the Milky Way emerge from the heavens**

The midwinter Milky Way

Take in the celestial targets of our home Galaxy with **Stuart Atkinson**'s winter observing tour

Seeing the misty, mottled arch of the Milky Way spanning the sky late on a clear summer night is one of the most enjoyable and memorable experiences for astronomers. It's right up there with your first view of Saturn's rings through a telescope and seeing a bright fireball skip and flare across the sky during a meteor shower. But why discuss the Milky Way at this time of year? Everyone knows that you can only see the Milky Way during the summer – that it's a 'summer sight', right?

Wrong. The Milky Way is still there on these frosty winter nights, it's just not as dramatic or obvious. While the summer Milky Way is a naked-eye wonder, a broad trail of starry froth and foam that splits the sky in two, the winter Milky Way is not so obvious and more of a spectacle to seek out. It's dappled on the sky, and if you take the time and trouble to look at it you'll be rewarded with some lovely sights. You'll see another side of the Milky Way; instead of the bright gaseous nebulae of summer, such as the famous Lagoon and Trifid Nebulae, what you will see is a host of sparkling star clusters.

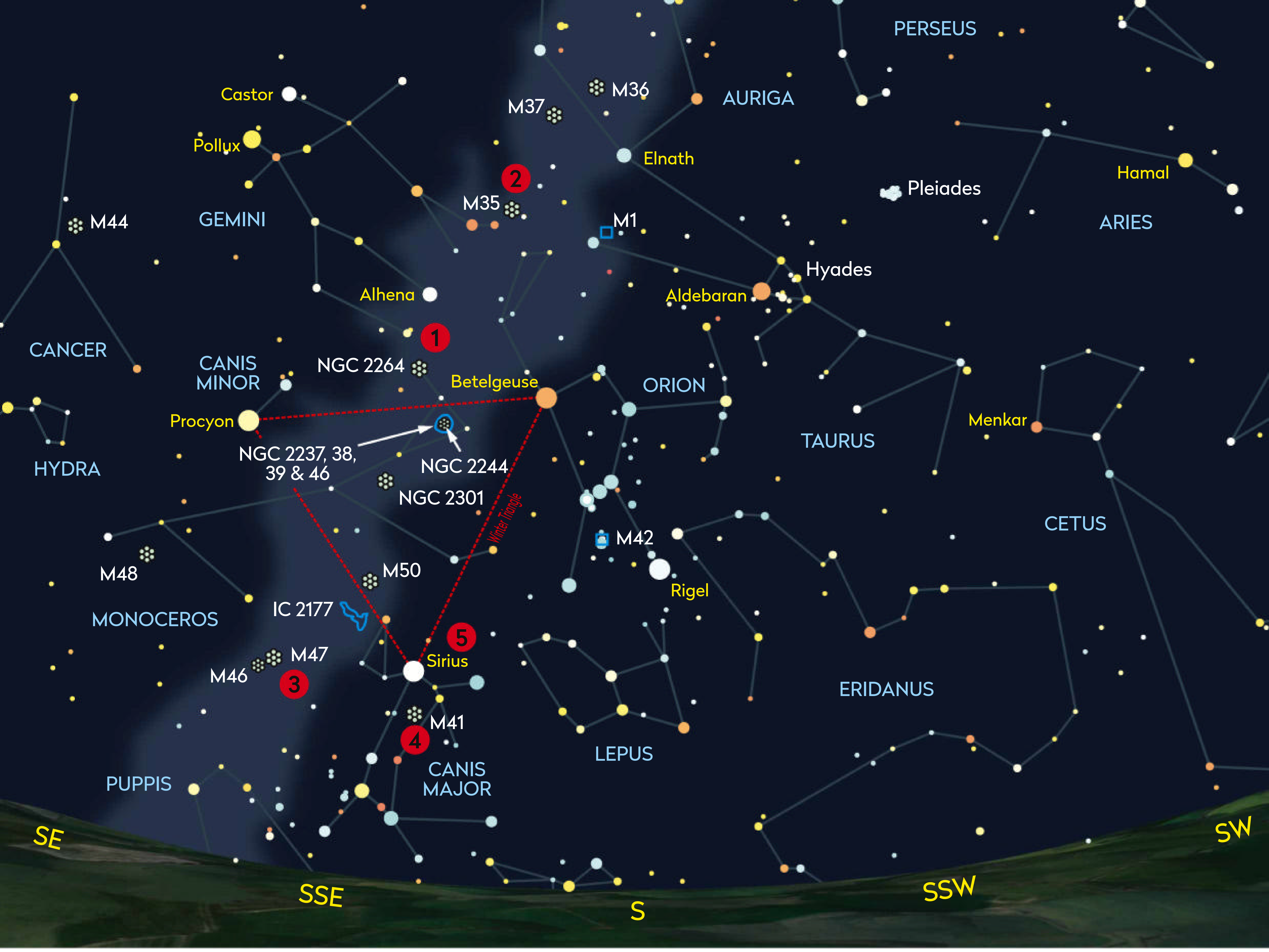
We're going to go on a tour of the midwinter Milky Way and take in some of these sights. Half are visible to the naked eye, and you'll need a pair of binoculars or a small telescope to see the rest. One thing's for sure, all of the sights are worth tracking down after you've taken your obligatory nightly look at the Pleiades and the Orion Nebula.

On the next clear, frosty night, before starting the tour pull on several pairs of socks and wrap up in your warmest jacket, hat and gloves. If you look like a seven-year-old child who has been dressed by their mum for a walk on a cold, snowy day, you'll be fine.

Head out at around 11:30pm and go to the darkest spot you can find. Straight away you'll see the constellation of Orion, the Hunter standing above the southern horizon, looking splendid with his famous Belt of three icy blue-white stars pulled tightly around his waist and ruddy-hued Betelgeuse (Alpha (α) Orionis) glowing at his shoulder.

All the objects on this tour lie close to Orion, in the southern part of the sky. Before you begin the tour, let your eyes adapt properly to the darkness; this takes about half an hour. Then let us embark! ►

WILL GATER



▲ Although faint at this time of year, the plane of the Milky Way, and the clusters within it, can be seen off the shoulder of Orion

Sights for setting off

The first targets can all be seen with the naked eye under good conditions, but binoculars will bring out their beauty

1. The Christmas Tree Cluster, NGC 2264

Located a short distance above and left of Betelgeuse (Alpha (α) Orionis), this open star cluster is 2,200 lightyears away and spans about 25 lightyears. At mag. +4.0 it's easy to see with the naked eye as a small smudge of light. It contains around 80 stars, and gets its nickname from the fact that observers think it resembles a Christmas tree when viewed through a telescope. The Cone Nebula is nearby, but is too faint to see without a large telescope.

2. The Shoe-Buckle Cluster, M35

One of the most popular star clusters in the northern sky, M35 can be found high above Orion, close to the foot of one of the Twins of Gemini, which explains its (little-used) nickname. At mag. +5.0, it's a visually large object and on a clear night is easy to see with the naked eye as a misty patch above Orion. M35 contains perhaps 500 stars, and the brightest hundred or so are a lovely sight through binoculars and small telescopes, looking like spilled salt grains. The cluster is approximately 35 lightyears across and lies 3,000 lightyears away from us.

3. M47

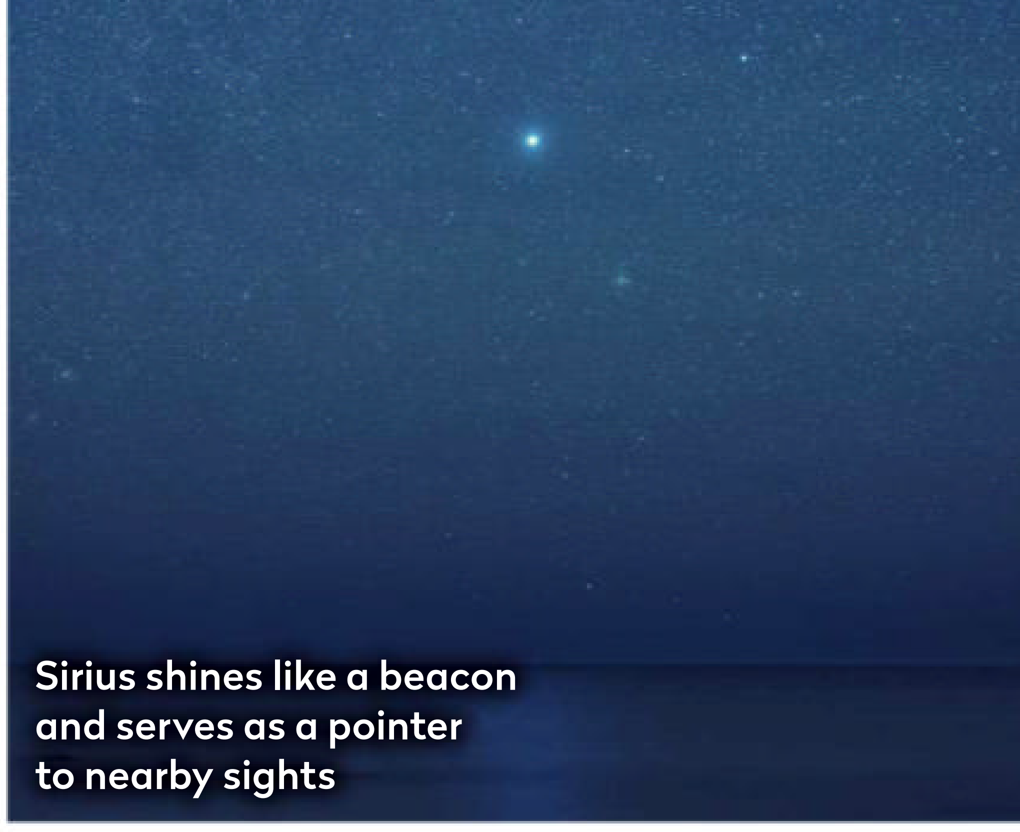
Often overlooked because of the bigger, brighter star clusters around it, M47 is a treat to observe on a frosty night. This loose cluster of around 50 stars can be found to the upper left of Sirius (Alpha (α) Canis Majoris) and covers an area of sky the same size as the Moon. At mag. +4.4 it is an easy naked-eye object if you take the time to look for it. M47 is 1,600 lightyears away from our Solar System.

4. The Little Beehive Cluster, M41

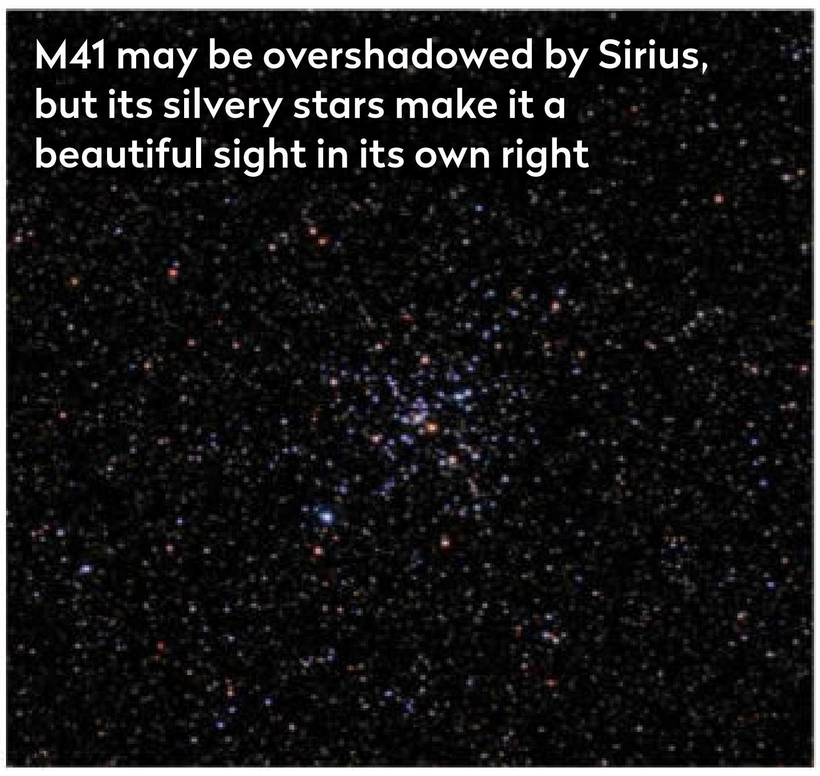
If this bright, mag. +4.5 open star cluster were anywhere else in the northern sky it would be much

CHART BY PETE LAWRENCE, HANNES BACHLEITNER/CCDGUIDE.COM, MICHAEL DEGER/CCDGUIDE.COM, BERNHARD HUBL/CCDGUIDE.COM, CEDIC TEAM + BERNHARD HUBL/CCDGUIDE.COM, SHAUNL/ISTOCK/GETTY IMAGES

M47 is one of the least densely populated open clusters



Sirius shines like a beacon and serves as a pointer to nearby sights



M41 may be overshadowed by Sirius, but its silvery stars make it a beautiful sight in its own right

Near one of Gemini's feet, M35 is filled with an abundance of stars

▲ **NGC 2264 is said to resemble a Christmas tree, beneath which lies the Cone Nebula**

more famous and popular. But because it lies close to and directly beneath bright Sirius, which never rises high in the sky as seen from mid-latitudes, the Little Beehive Cluster is something of a 'tree-scraper' for many winter observers. If you have a clear, low southern horizon, on mid-winter nights you should be able to find M41 easily and it really is a lovely sight through binoculars and small telescopes, resembling a smaller version of M44, the Beehive Cluster in Cancer. The cluster is a long way away, more than 2,300 lightyears distant, and its 100 or so silvery stars cover an area of the sky as wide as a full Moon.

5. Sirius, the 'Dog Star'

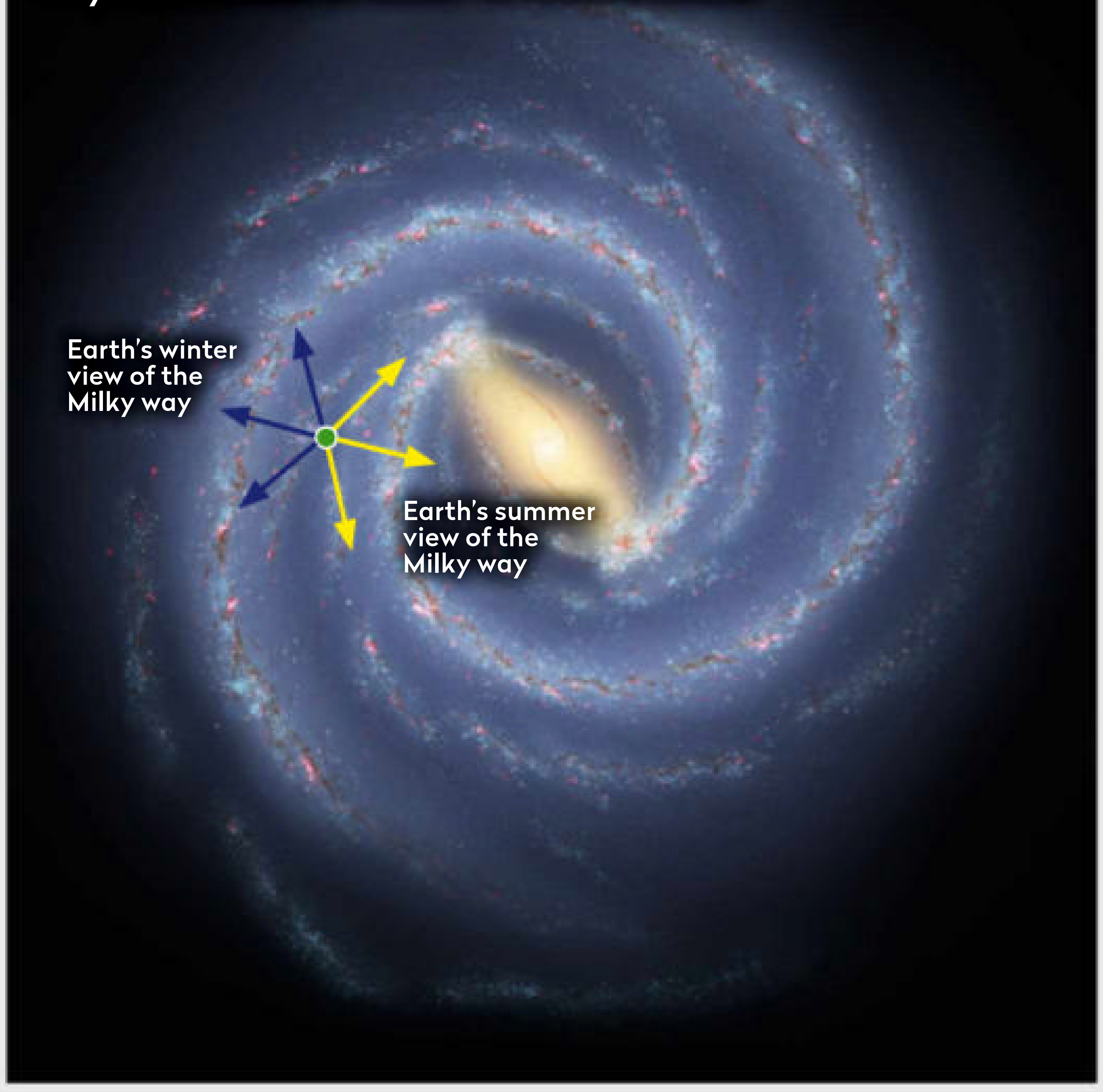
Shining down to the lower left of Orion's famous Belt, magnificent Sirius blazes away at mag. –1.46, making it the brightest star in the night sky by a significant margin. Because it lies so low in the sky, at mid-latitudes Sirius is often seen through lots of turbulent air that boils above the horizon. As a result, its light gets broken up, causing it to sparkle and flash dramatically, much like a finely cut jewel catching the sunlight. Sitting nine lightyears away from Earth, Sirius – also known as the 'Dog Star' – is the fifth closest star to our Sun.

The geometry of the winter Milky Way

The view of our Galaxy in the night sky reveals how our perspective changes as Earth orbits the Sun

If you've ever wondered why the Milky Way looks so different in the winter compared to its appearance in the summer, it is because of our Solar System's position within the great Catherine wheel of sparkling stars that is our Galaxy. When we look out from Earth on a clear night during the summer months we're looking in towards the centre of the Milky Way, and also looking through one of its densely packed, nearby spiral arms, so we see a lot of stars – countless billions of them, in fact – looking like mist or smoke. In winter however, those parts of the Milky Way are hidden from us by the Sun and we're looking outwards to where the stars are much less densely packed, so the Milky Way looks a lot less striking. But it's still there and if you go to a dark-sky site, you'll see it easily enough. Furthermore, if you take the time to sweep your eyes, binoculars and telescopes along it, you'll see lots of fascinating objects embedded within it too.

Earth's outlook on the Galaxy changes as it orbits the Sun; in summer we look towards the Milky Way's centre and in winter we look outwards



Taking a closer look

Break out your binoculars or telescope for the next part of the tour and explore more of the Milky Way's deep-sky objects

▲ Take full advantage of the magnification offered by your observing equipment to help you find the Milky Way's hidden gems

6. The Rosette Nebula

Photographs show the Rosette Nebula as a pretty, rose-like bloom of pink and red gas to the left of Betelgeuse. But despite shining at mag. +5.5, its width and low surface brightness means that with the naked eye, it appears as a vague smudge, even on the darkest of clear nights. The nebula is best viewed through binoculars or a small telescope, but even then it can look like a ghostly patch. For most amateur photographers it's probably best enjoyed photographically, on long-exposure images, giving you a good reason, perhaps, to start your journey into astrophotography (see the 'Photographing the Milky Way' box, on page 33).

7. The Heart-Shaped Cluster, M50

When you look at this 3,200 lightyear-distant, mag. +5.9 open star cluster through your binoculars or telescope you will see a handful of brighter stars surrounded by much fainter ones. But you may be left scratching your head with regard to how the Heart-Shaped Cluster, M50, got its nickname, because it's never looked anything like a heart to me. Nevertheless, this target is still worth tracking down on a cold winter's night and you'll find it glittering serenely above and slightly to the left of Sirius.

8. M46

This rich, mag. +6.0 open star cluster can be found a short distance over to the left of Sirius and it contains between 100 and 500 'pollen grain' stars, surrounded by a cage of brighter suns. If you look at M46 through a telescope at high magnification, you might be able to see that a tiny planetary nebula appears to be embedded within it. In fact, this is all a trick of perception, as NGC 2438 is several thousand lightyears closer to us than M46 and isn't remotely associated with the cluster.

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy

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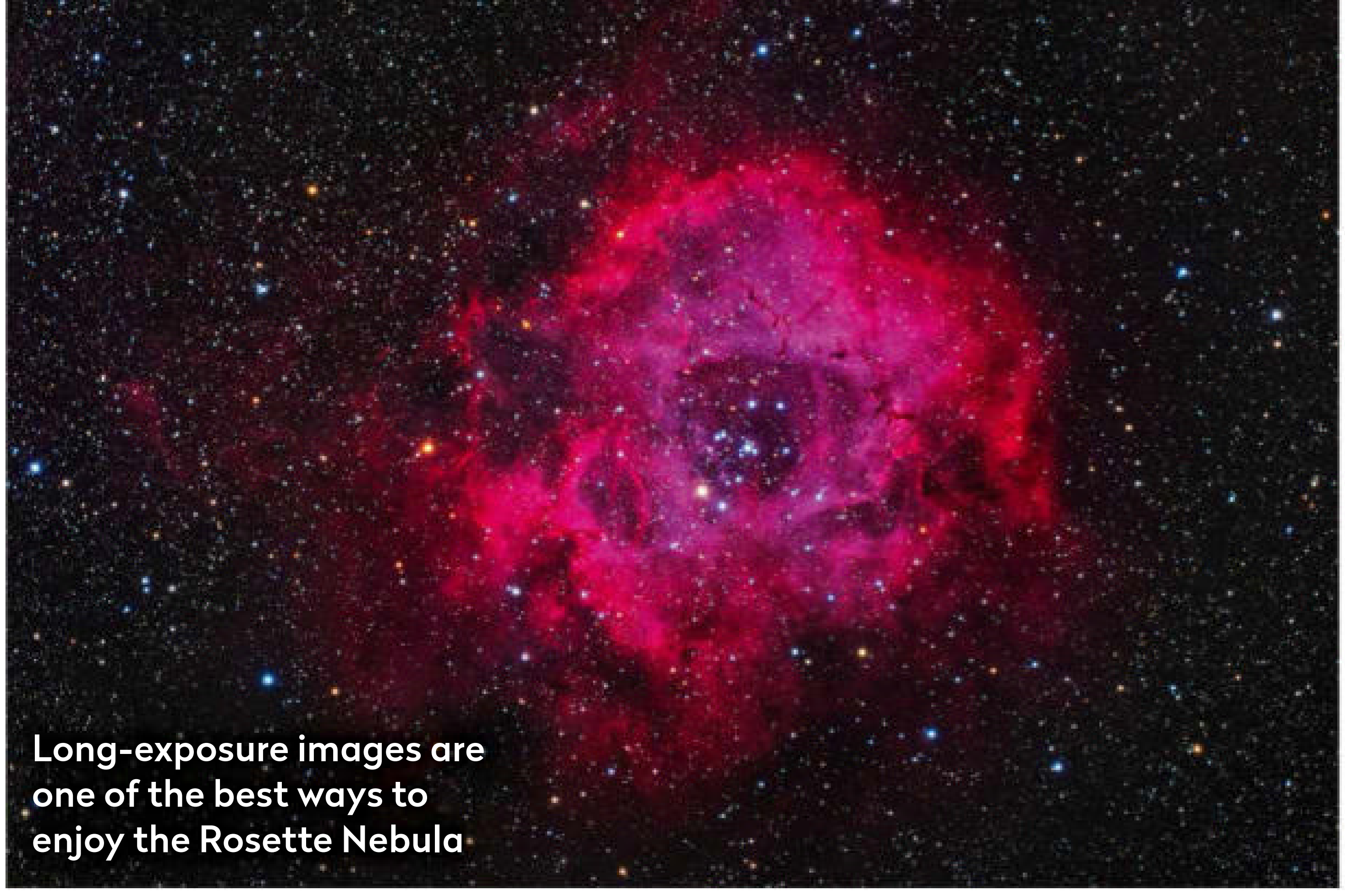
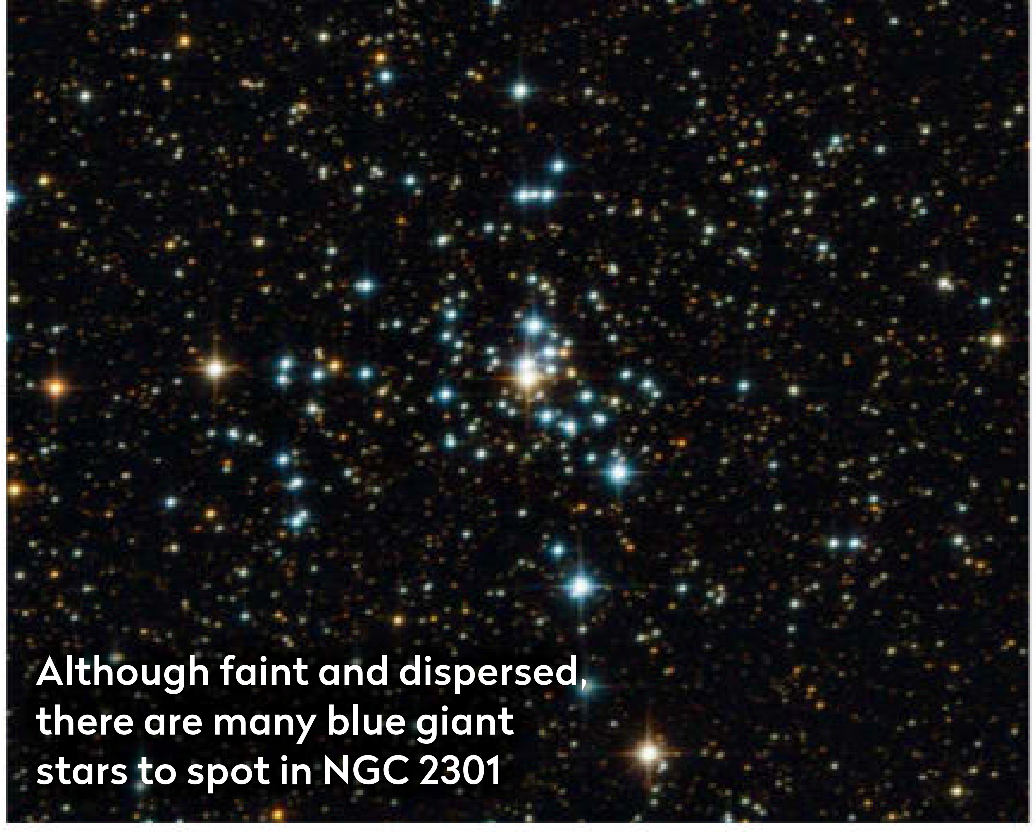
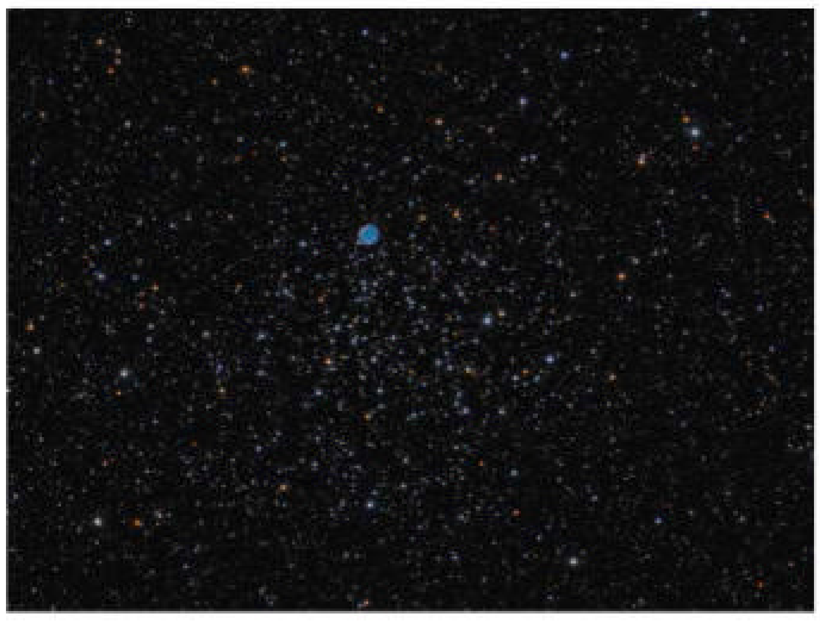
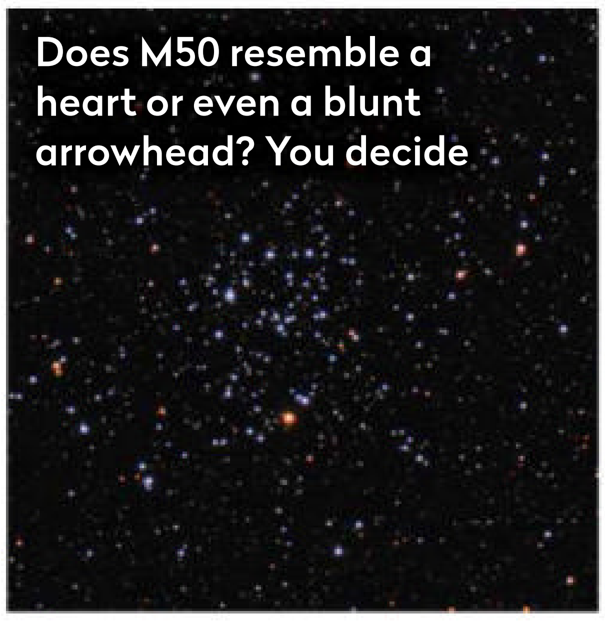


Long-exposure images are one of the best ways to enjoy the Rosette Nebula

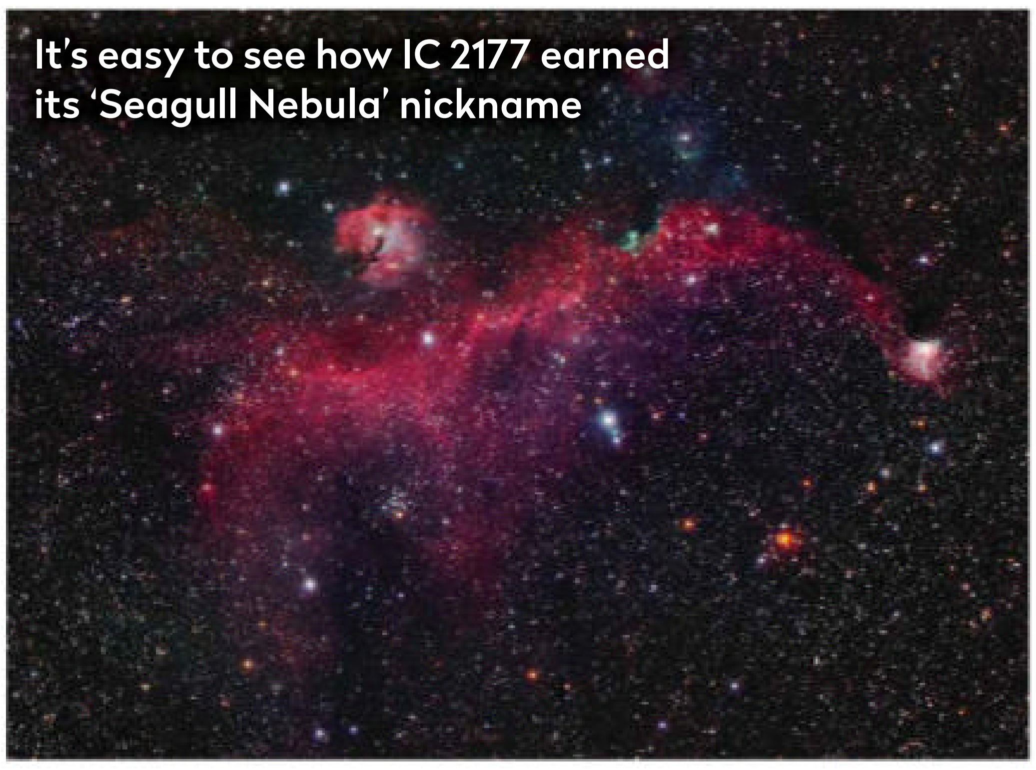


Although faint and dispersed, there are many blue giant stars to spot in NGC 2301





Does M50 resemble a heart or even a blunt arrowhead? You decide



It's easy to see how IC 2177 earned its 'Seagull Nebula' nickname

▲ Although M46 lies thousands of lightyears away, the open cluster is vast and has an apparent diameter that is almost equal to that of a full Moon

9. Hagrid's Dragon Cluster, NGC 2301

NGC 2301 has a number of aliases. Besides its New General Catalogue designation, it's also known as Hagrid's Dragon Cluster and Copeland's Golden Worm. But despite boasting these dramatic nicknames, it is likely that few people reading this have even heard of this mag. +6.0 loose, open cluster. This is hardly surprising because NGC 2301's stars are faint and spread far apart. In fact, through a telescope it looks more like a ragged line of stars than an open cluster. But with the help of a little imagination, you might just be able to see the shape of a dragon. When you do, perhaps you'll consider a third nickname for the cluster, Norberta, the name of the dragon that belonged to Rubeus Hagrid in the *Harry Potter* books. You'll find the cluster roughly halfway between Orion's Belt and Procyon (Alpha (α) Canis Minoris), the brightest star in Canis Minor.

10. The Seagull Nebula, IC 2177

Just a short distance above and to the left of the brilliant star Sirius lies a very faint nebula surrounding an 8th magnitude star. At mag. +10.0, the Seagull Nebula will present you with a real Christmas challenge, because it can only be seen through a telescope on a beautifully clear, Moon-free night from a site that's free from light pollution. Even if you do pick it up as a vaguely M-shaped smudge, you'll probably wonder why IC 2177 is nicknamed after a screeching, chip-stealing seaside bird! But the Seagull's wings and head do appear quite pronounced in long-exposure photographs.

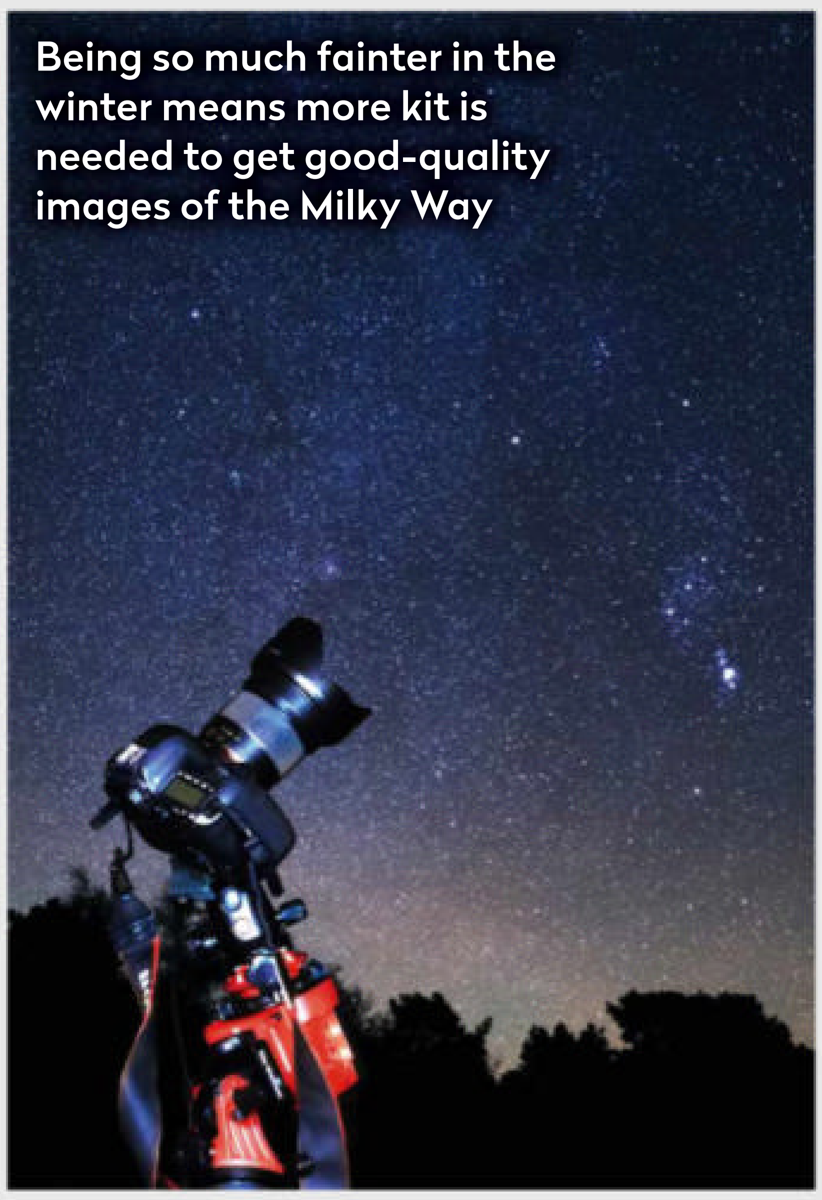
Photographing the Milky Way

If you're observing the winter Milky Way, why not see if you can capture an image of it as well?

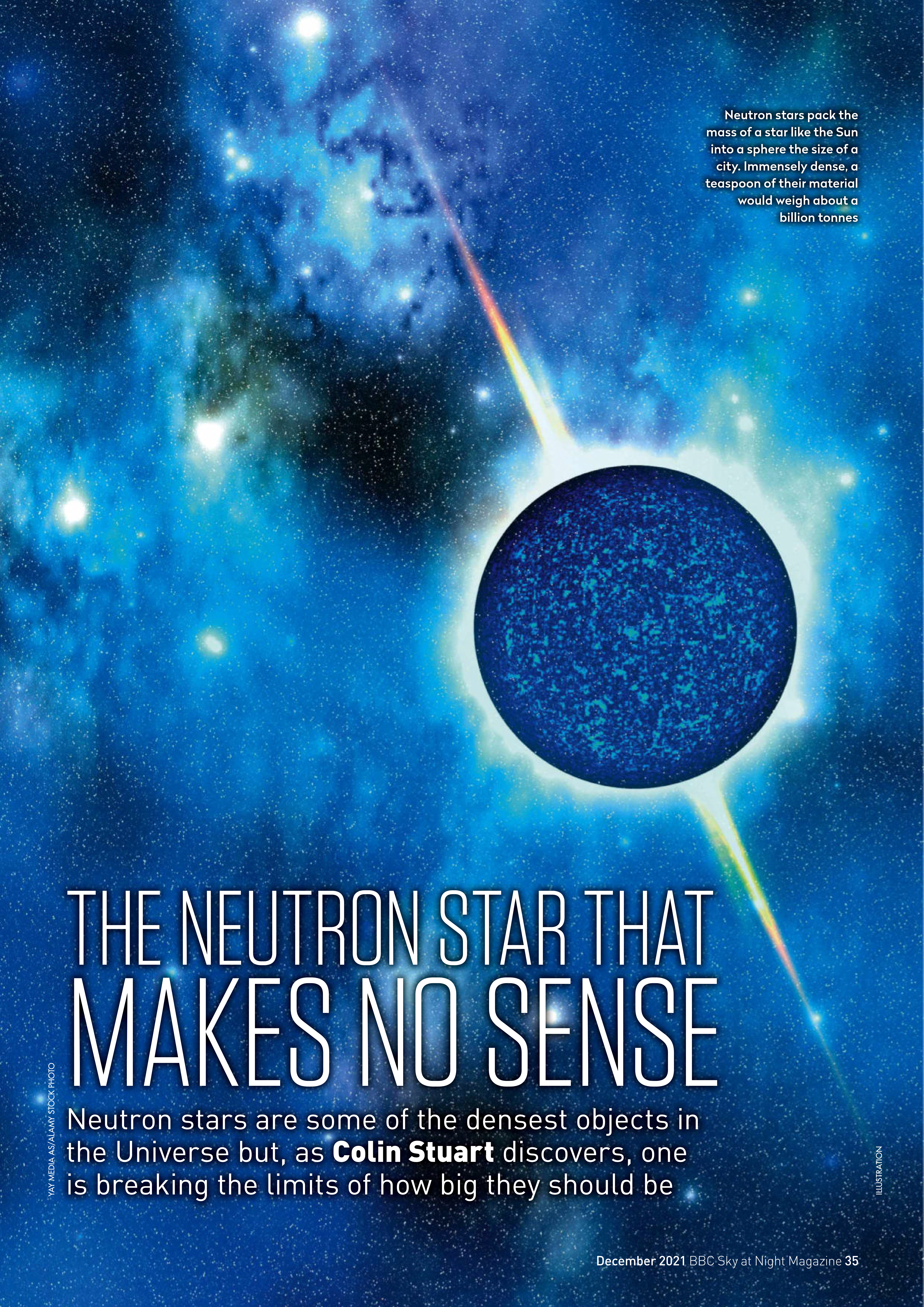
Almost every issue of *BBC Sky at Night Magazine* features at least one gorgeous image of the bright summer Milky Way, some taken with just mobile phones. If you want to photograph the winter Milky Way however, you'll need a digital SLR camera on a tripod or a tracking mount, because it's much fainter than its summer counterpart, and too faint and diffuse for most phone cameras to pick up. Fit your camera with a wide-angle lens, set it to an ISO of 800 or higher, point it towards Orion, the Hunter and then nudge it to the left so Orion is on the right of the frame.

Using a cable release to reduce vibrations, take the longest exposure you can get away with before the stars trail or your local light pollution fogs the image. You'll see a misty band to the left of Orion, stretching from beside Sirius up into the constellations of Perseus and Cassiopeia, much fainter than the beautiful summer Milky Way, but still there. If you take multiple images, you can stack them using free software to make the equivalent of one very long exposure, and then process that stacked image to bring out the faint stars of the winter Milky Way.

For more astrophotography tips, visit **www.skyatnightmagazine.com/astrophotography**



Being so much fainter in the winter means more kit is needed to get good-quality images of the Milky Way



Neutron stars pack the mass of a star like the Sun into a sphere the size of a city. Immensely dense, a teaspoon of their material would weigh about a billion tonnes

THE NEUTRON STAR THAT MAKES NO SENSE

Neutron stars are some of the densest objects in the Universe but, as **Colin Stuart** discovers, one is breaking the limits of how big they should be

YAY MEDIA AS/ALAMY STOCK PHOTO

ILLUSTRATION

The most massive neutron stars should also be the smallest – more mass means stronger gravity and therefore a more compact, tightly squeezed object. At least, that is how it's supposed to work

The Universe is littered with the most unlikely objects. In the depths of space lie dead stars, each containing more mass than the Sun but crammed into a space the size of a city. They are so tightly packed that a single teaspoon of their contents would weigh more than Mount Everest – or about as much as every human that has ever lived. What's more, they spin multiple times a second, are highly magnetised and spit out rotating beams of radiation like celestial lighthouses.

Astronomers call these enigmatic objects neutron stars. They form when a medium-sized star reaches the end of its life and explodes as a supernova, after which it leaves an incredibly dense core behind. Their name comes from the sub-atomic particles called neutrons, which you usually find inside the nuclei of atoms. The intense pressure inside a neutron star takes the other two mainstays of the atom – protons and electrons – and crushes them together to form yet more neutrons. In total, a neutron star is 90 per cent neutrons – effectively, each one is a giant, city-sized atomic nucleus.

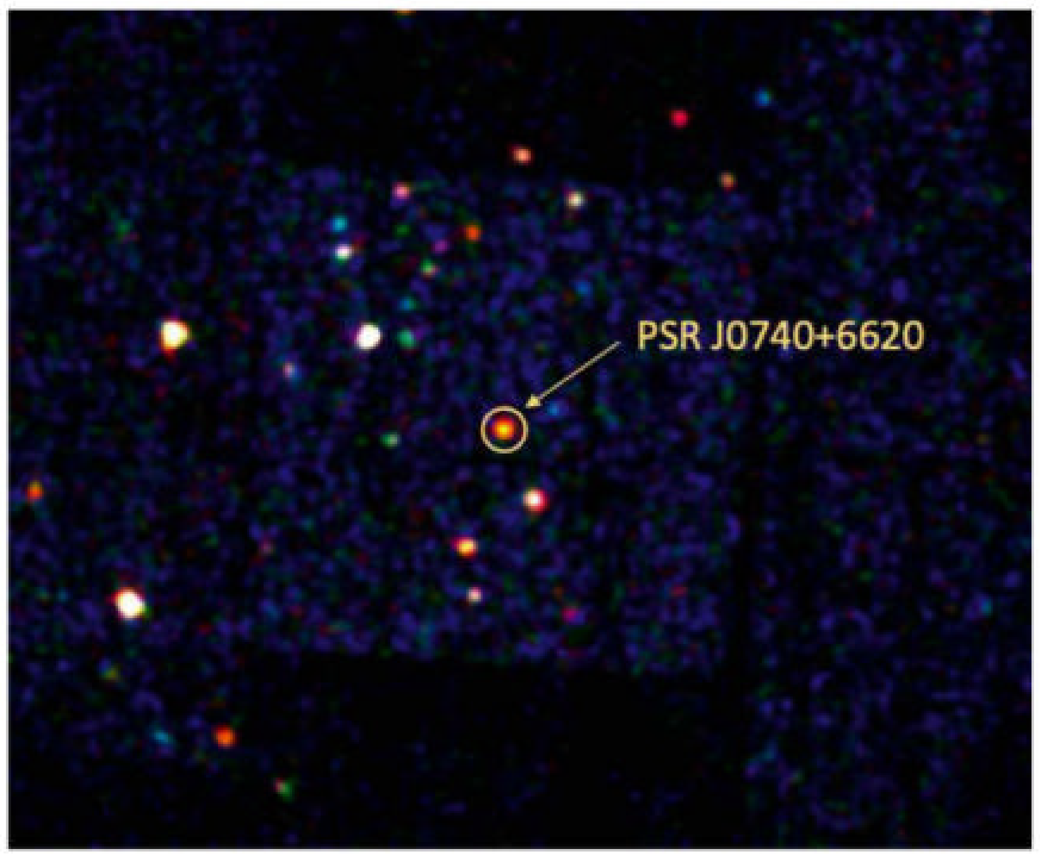
Balanced forces

Neutron stars only exist because of a delicate balance of forces. On one hand you have gravity trying to collapse the star further. (In fact, research published in July 2021 found that the gravity of neutron stars is so extreme that mountains on their surface can barely reach a millimetre in height.) Yet resistance to gravitational collapse comes in the form of something called degeneracy pressure. This is generated because there comes a point when it is too hard to squash nuclear material closer together and so the two opposing forces balance each other out.

This means that the most massive neutron stars should also be the smallest – more mass means stronger gravity and therefore a more compact, tightly squeezed object. At least, that is how it is supposed to work. So you can imagine the surprise for astronomers when, in 2019, they stumbled across a seemingly impossible neutron star, one that currently makes no sense: a neutron star that has a density far greater than its vast size should allow. Explaining its existence won't just answer important questions about neutron stars that we've been asking for decades, it could also tell us more about nuclear physics and gravity to boot.

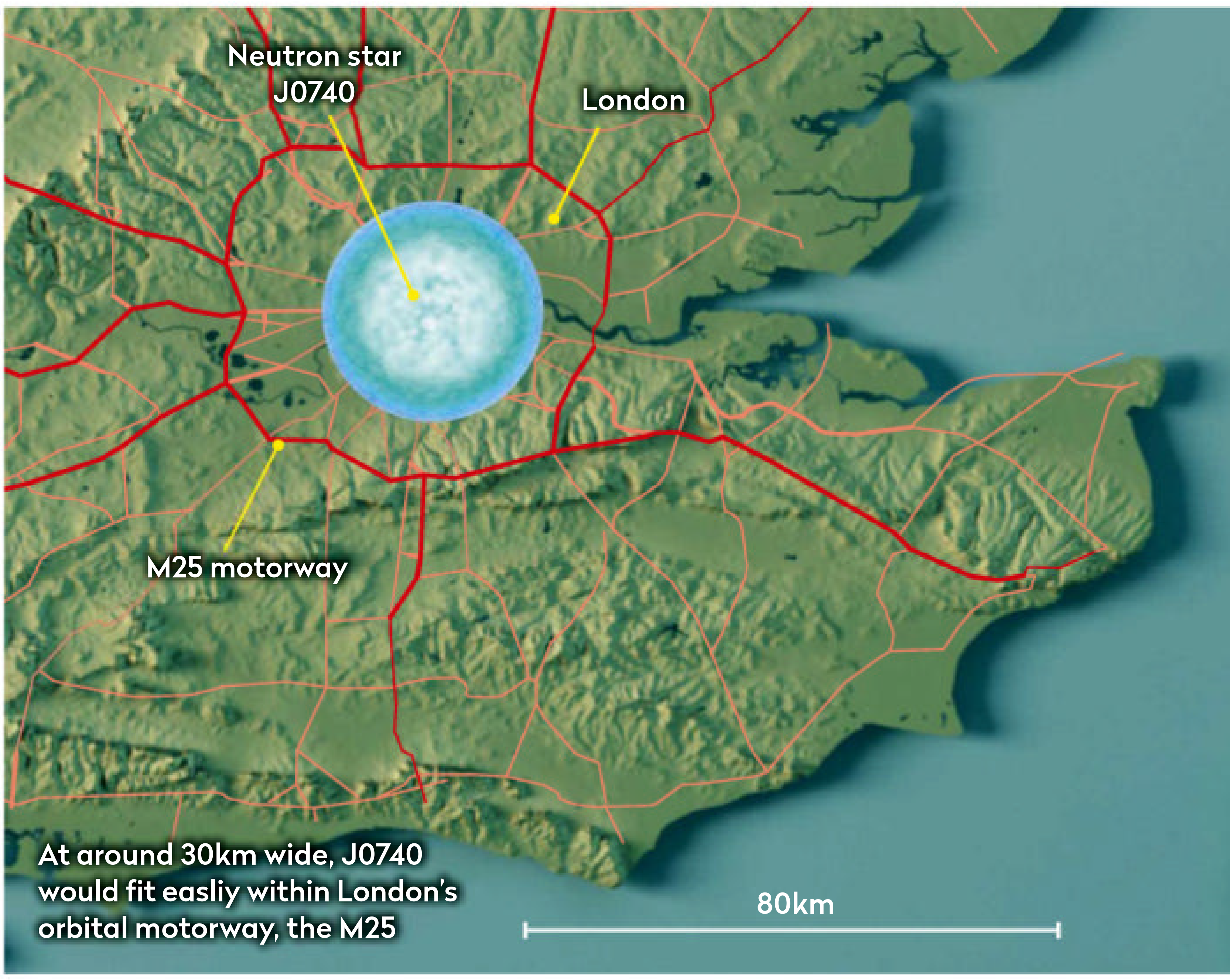
The neutron star in question is called J0740 and sits 3,600 lightyears away in the constellation of Camelopardalis, the Giraffe. Like many stars, it exists in a pair (or binary system). Its partner, 6620, is a white dwarf, another type of dead star. Anna Watts, from the University of Amsterdam, is part of team that's been studying J0740 and other neutron stars using NASA's Neutron star Interior Composition Explorer (NICER), an X-ray telescope attached to the International Space Station (ISS).

"As these objects spin, their brightness changes because there are hotspot regions on their surfaces," says Watts. "We can use this characteristic to build up maps of those surfaces."



◄ An image of J0740 and its binary companion 6620, as taken by the NICER instrument on the ISS, using data from the XMM-Newton space telescope

▼ To analyse detail on J0740 – a neutron star the size of London – from a distance of 3,600 lightyears requires extensive periods of observation



At around 30km wide, J0740 would fit easliy within London's orbital motorway, the M25

FRANKRAMSPOTT/ISTOCK/GETTY IMAGES, ESA, NASA

What is 'nuclear pasta'?

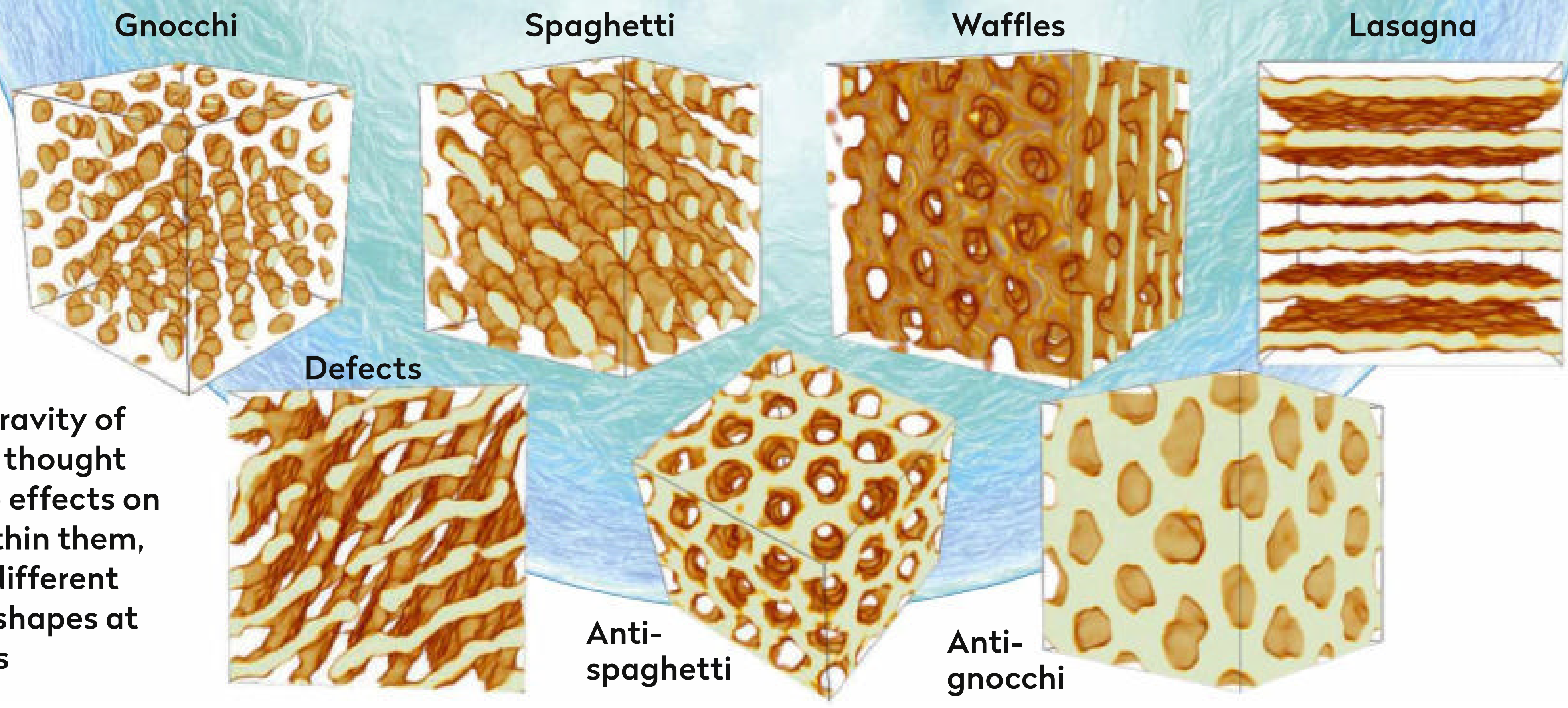
Strange shapes of spaghetti and other pasta types thread their way around neutron stars

When you crush the mass of a star down to the size of a city you put the constituent material under extreme amounts of pressure. The neutrons get distorted into structures of different shapes. These structures are 10 billion times stronger than steel, making them the strongest known material in the Universe.

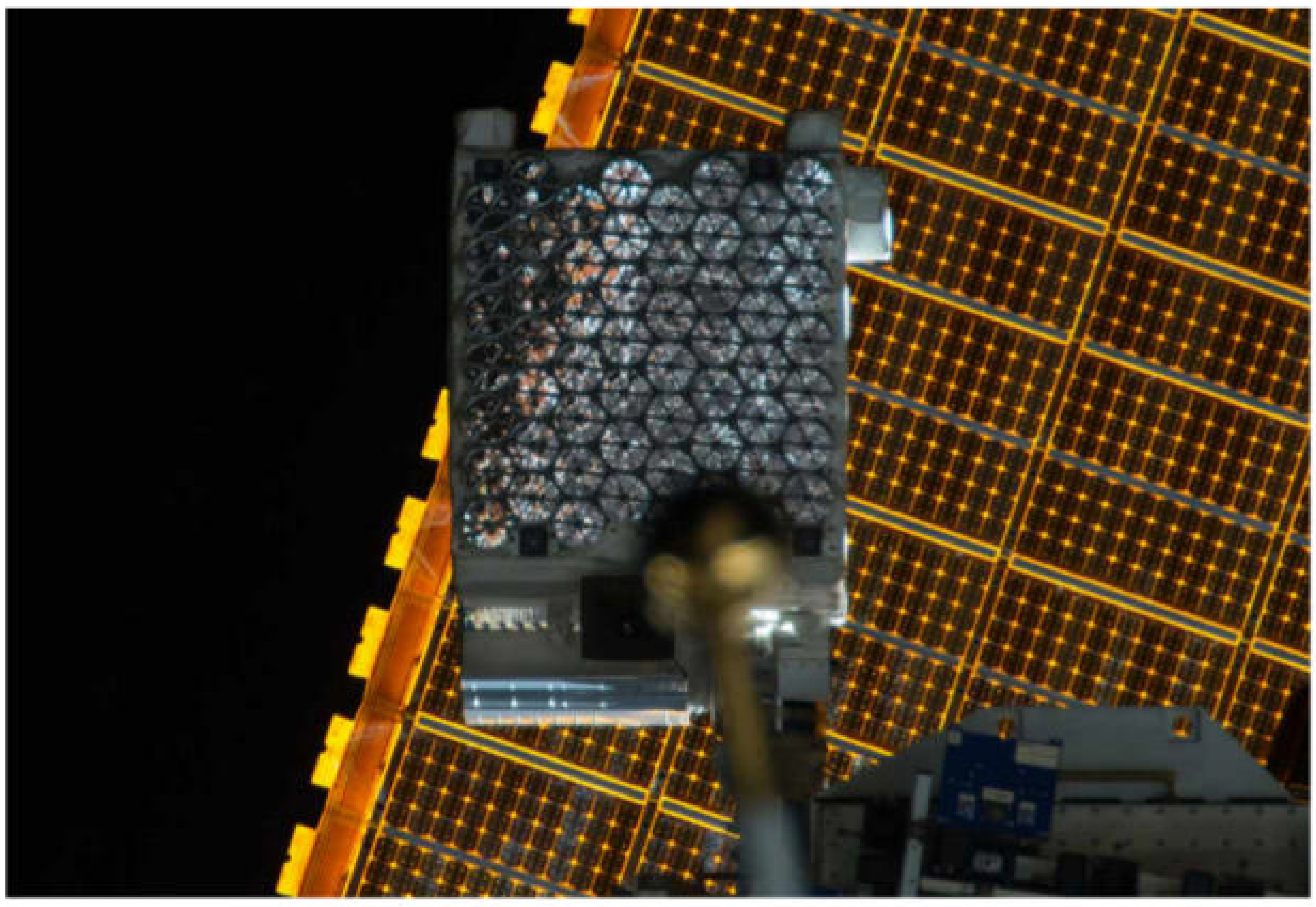
As they resemble different types of pasta, they have been named after the Italian foodstuff. Near the surface of the neutron star, this 'nuclear pasta' takes the form of bubbles called gnocchi. Go deeper and the growing pressure compacts the pasta into a shape more like spaghetti, and go deeper still and it is compressed into flat sheets of lasagne. Although anti-spaghetti and anti-gnocchi are not pre-pasta courses, there are materials inside neutron stars with holes shaped like those types of pasta too.

The layers of nuclear pasta in a typical neutron star are about 100m thick, but still weigh more than 3,000 Earths.

So far nuclear pasta remains hypothetical, conjured into existence in the early 1980s and backed up in the last few years by highly detailed computer simulations. But it is also thought to be unstable, meaning it could be producing ripples in space called gravitational waves. If scientists could locate these it would back up the idea.



► The intense gravity of neutron stars is thought to have strange effects on the material within them, forming it into different 'nuclear pasta' shapes at different depths



▲ The Neutron Star Interior Composition ExploreR (NICER) X-ray telescope looks out into deep space from its perch on the ISS

To accurately chart the surface detail of an object the size of London from a distance of over 3,600 lightyears (or 34 quadrillion kilometres) is quite some feat. It takes three to four weeks of observations over the course of a year. These surface maps are one of the tools Watts and her colleagues use to estimate the mass and size (radius) of neutron stars such as J0740.

It turns out that J0740 is the most massive neutron star we've ever found, tipping the scales at 2.1 times the mass of the Sun. So it should also have the smallest radius. Except it doesn't. It's just as wide as another neutron star with only two-thirds as much mass. That means the material inside J0740 isn't as compressible – or 'squishy' as astronomers tend to refer to it – as they thought. That potentially gives us clues about what's going on inside the core, which is important because of all the layers a neutron star has, the core is the least understood.

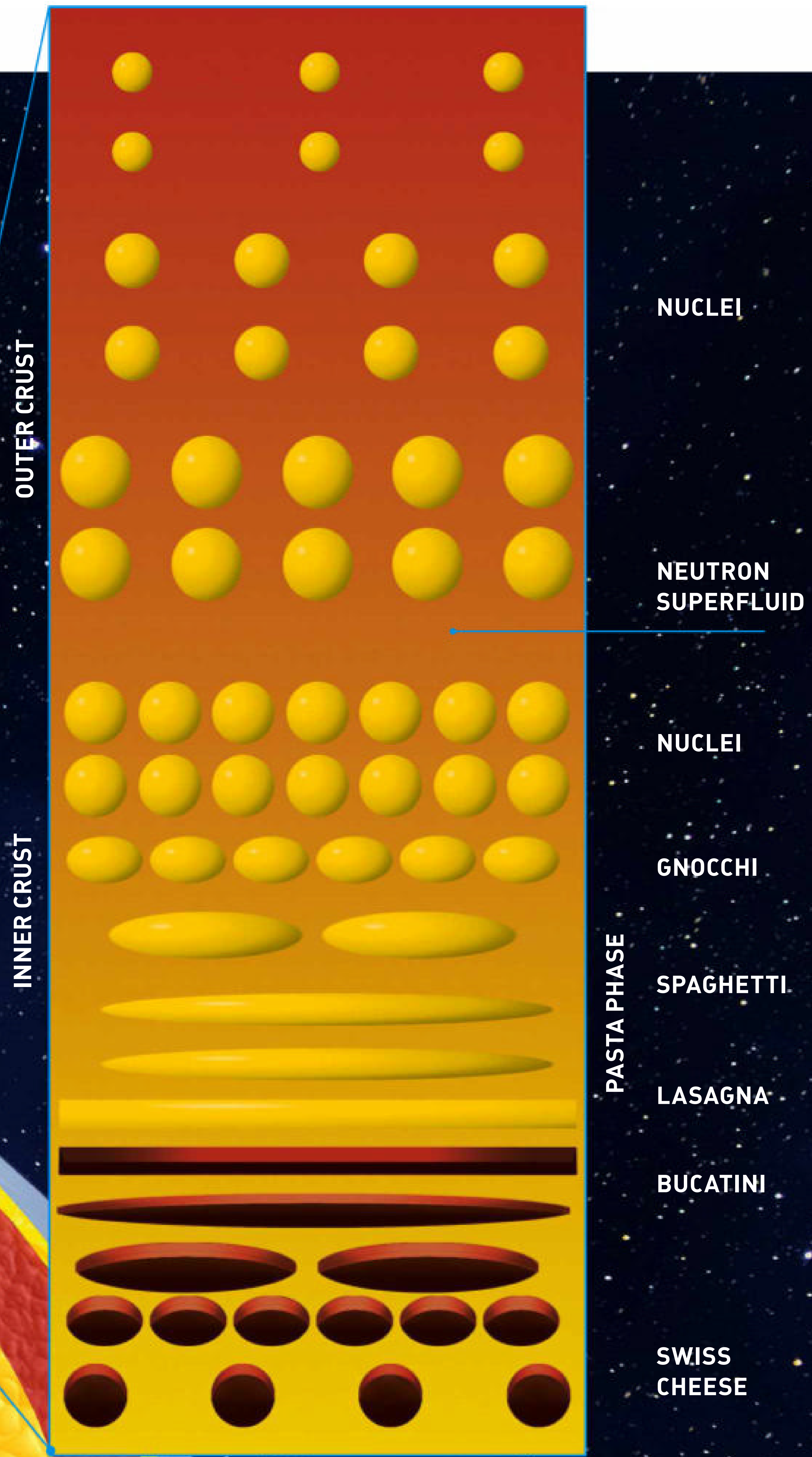
Quark soup

"There's been a huge debate about quarks," says Watts. Quarks are the particles that make up protons and neutrons. The intense pressure in the core of a neutron star could break the neutrons apart, forming a quark 'soup'. It takes energy to break the neutrons down, which means there would be less available to resist gravity. That should make the neutron star more compressible and smaller, but Watts argues that's now harder to justify given J0740's surprisingly large size. "It doesn't rule them out completely, but those models look quite unlikely," she says.

Joseph Kapusta, from the University of Minnesota, is one of the researchers examining the possibility of ►

Anatomy of a neutron star

A neutron star has a similar structure to our planet, with an atmosphere, crust and core. But what goes on inside is very different

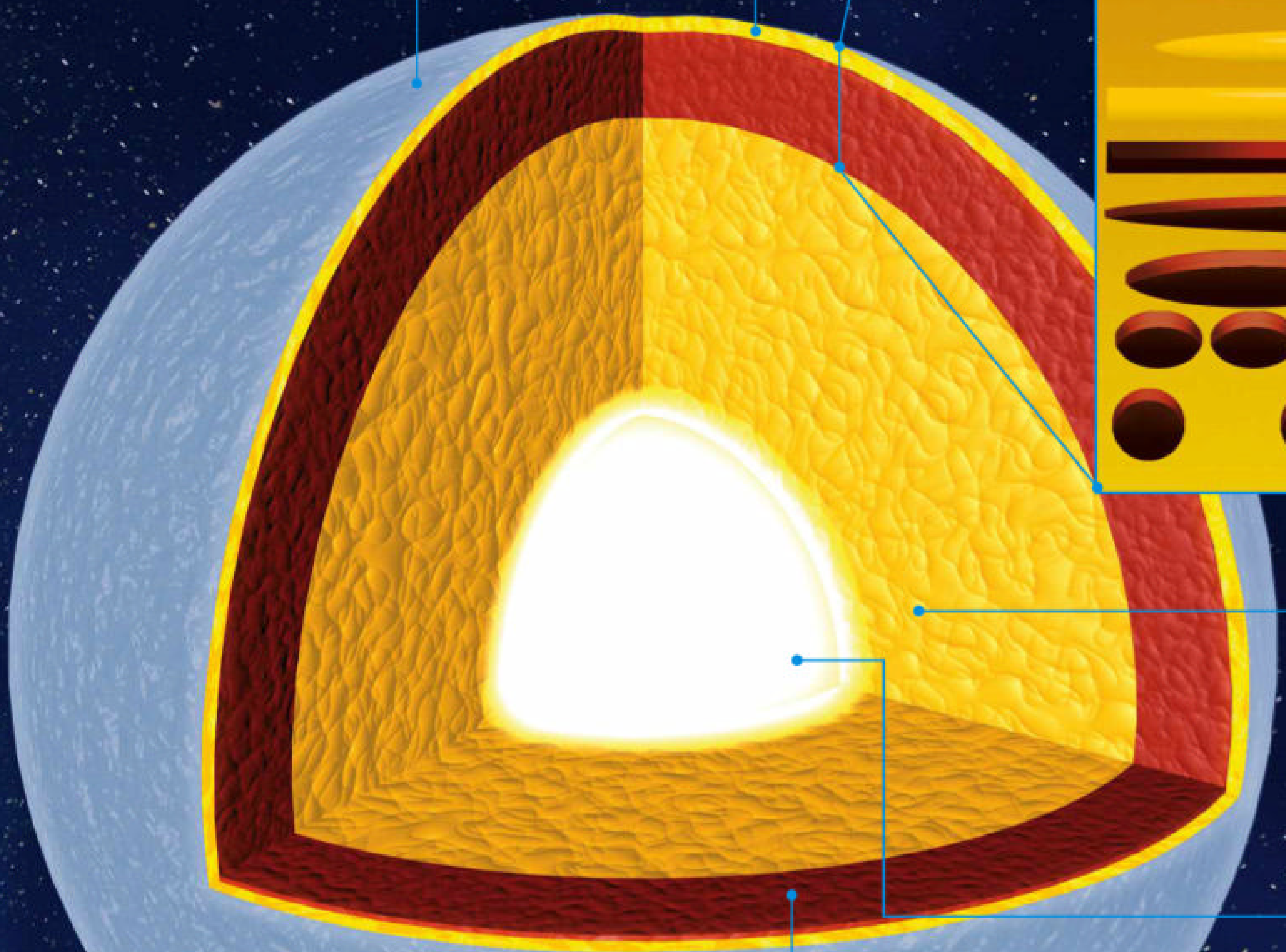


ATMOSPHERE

The gravity of the neutron star maintains an atmosphere of hydrogen, helium and carbon heated to around 2 million °C. It's just a few thousandths of a millimetre thick.

OUTER CRUST

The outer crust is made of a mixture of electrons and atoms that have had some or all of their electrons removed (known as ions).



OUTER CORE

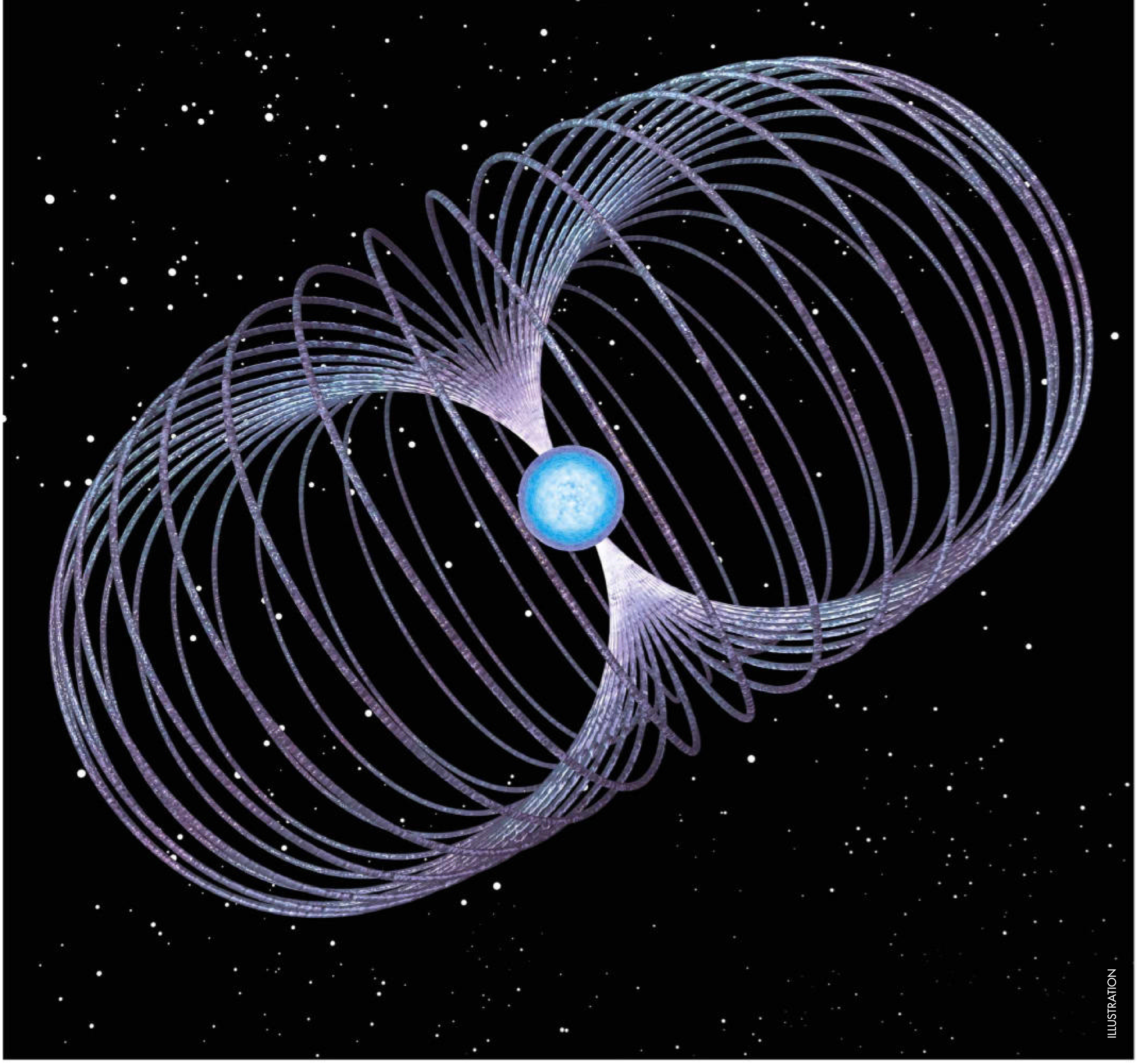
Here you will find superconducting protons. A superconducting material offers no resistance to electrical current and so the current can flow through it without losing any energy.

INNER CORE

The least understood part of a neutron star, the inner core could be made of a soup of quarks – the particles that make up protons and neutrons.

INNER CRUST

The neutron star's magnetic field holds a lot of sway in this region. It could help fragment the crust and generate starquakes. Material in the inner crust takes the form of electrons, neutrons and atomic nuclei.



▲ **Neutron stars have extremely strong magnetic fields, which may have an effect on the composition of the star's internal material**

▸ quarks in the core of a neutron star. "A mixture of quarks and ordinary nuclear matter could support a star up to 2.2 solar masses," he says, enough to encompass J0740 at 2.1 solar masses. He isn't convinced the NICER findings are enough to rule out his theory. "There are uncertainties in the estimates of the radius," he says. That could leave some wiggle room for a quark soup core.

For her part, Watts is busy hunting down other massive neutron stars to see if they also have unexpectedly large radii. NICER should be able to look at six neutron stars in total. "The dream is about 20," Watts says, but that will have to wait until the next generation of X-ray telescopes.

In the meantime, other teams of researchers have been busy trying to explain why J0740 isn't as squishy as it should be. Adrian Abac, from the University of San Carlos in the Philippines, argues that there's something our current neutron star models aren't accounting for: dark matter.

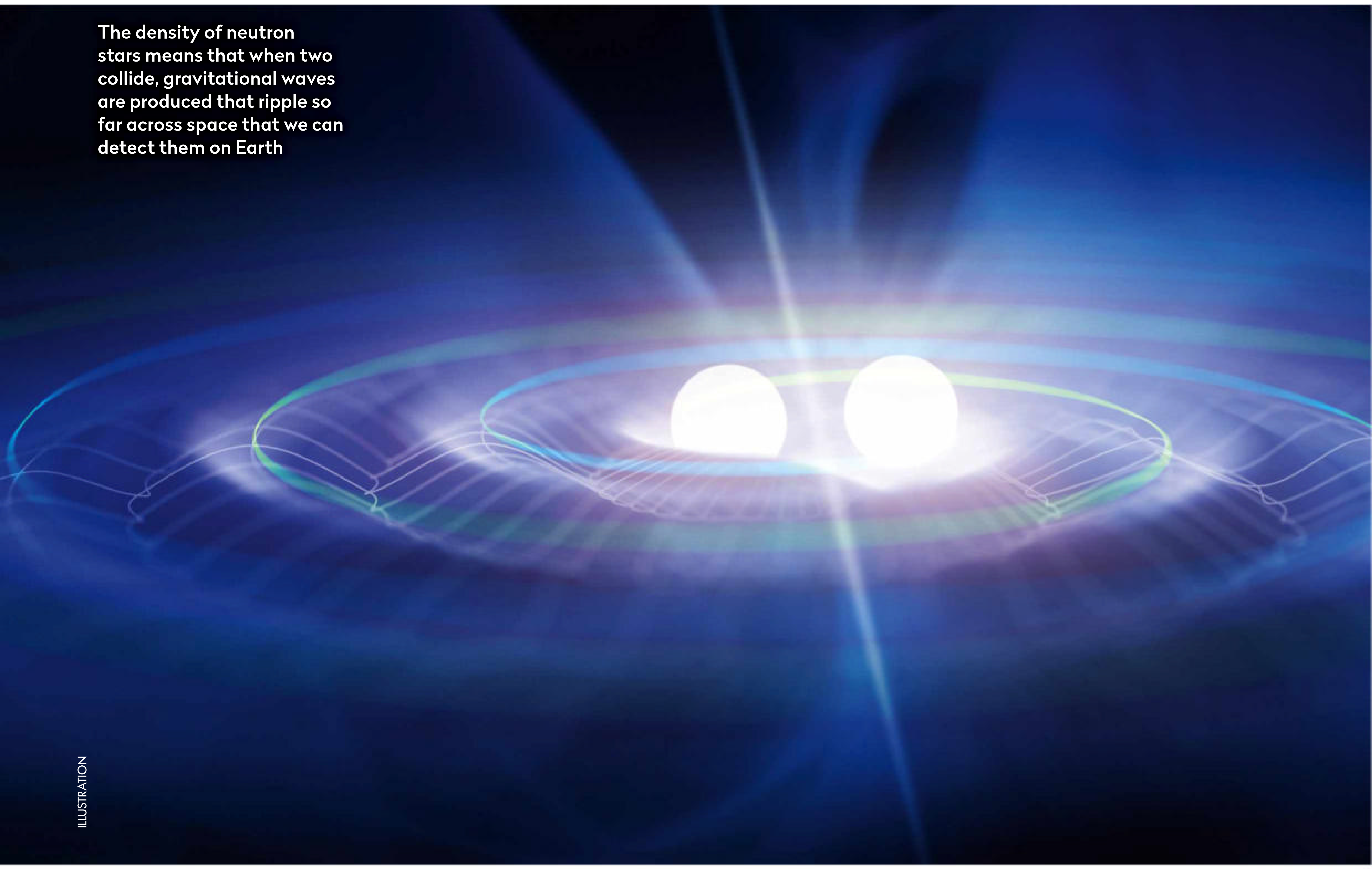
Dark matter is the mysterious, invisible glue thought to stick galaxies together. It's spread sparsely throughout space. In fact, just one milligram of dark matter will pass through you over the course of your life. Abac argues that it also gets caught up in the cores of neutron stars. When he added dark matter to his neutron star models, he found that it offered up an additional source of resistance to gravity, perhaps explaining why J0740 isn't as compressible as we expected.

Fan Ji, from Nankai University in China, has taken a different approach. He thinks the answer lies in the neutron star's inner crust rather than the core. Matter between the core and surface forms odd materials that physicists refer to as 'nuclear pasta' (see the 'What is nuclear pasta?' box on page 37). He found that if the inner crust is made of bubble-shaped material called 'gnocchi', then it can lead to a neutron star with a larger radius because the star is less compressible. Crucially however, this was the case for low mass neutron stars, not huge ones like J0740.

Magnetic pasta

There is another force that could be playing a role: magnetism. Some neutron stars have magnetic fields so strong that they would be able to wipe the information from all the credit cards on Earth while sitting halfway between us and the Moon. Helena Pais, from the University of Coimbra, Portugal, found that this super-strong magnetism affects the structure of the nuclear pasta, leading to a thicker inner crust. This may make a neutron star less squishy. ▸

INFOGRAPHIC BY PAUL WOOTTON, RUSSELL KIGHTLEY/SCIENCE PHOTO LIBRARY



The density of neutron stars means that when two collide, gravitational waves are produced that ripple so far across space that we can detect them on Earth

ILLUSTRATION

ANDREY VOLODIN/ALAMY STOCK PHOTO

▸ Finding out who is right is important work. There are few places in the observable Universe where you'll find nuclear matter under such extreme duress. J0740 is the perfect laboratory to put our best theories to the test, one that could rival traditional atom smashers such as the Large Hadron Collider on the French-Swiss border. It could teach us something valuable about nuclear physics in general, as well as about neutron stars.

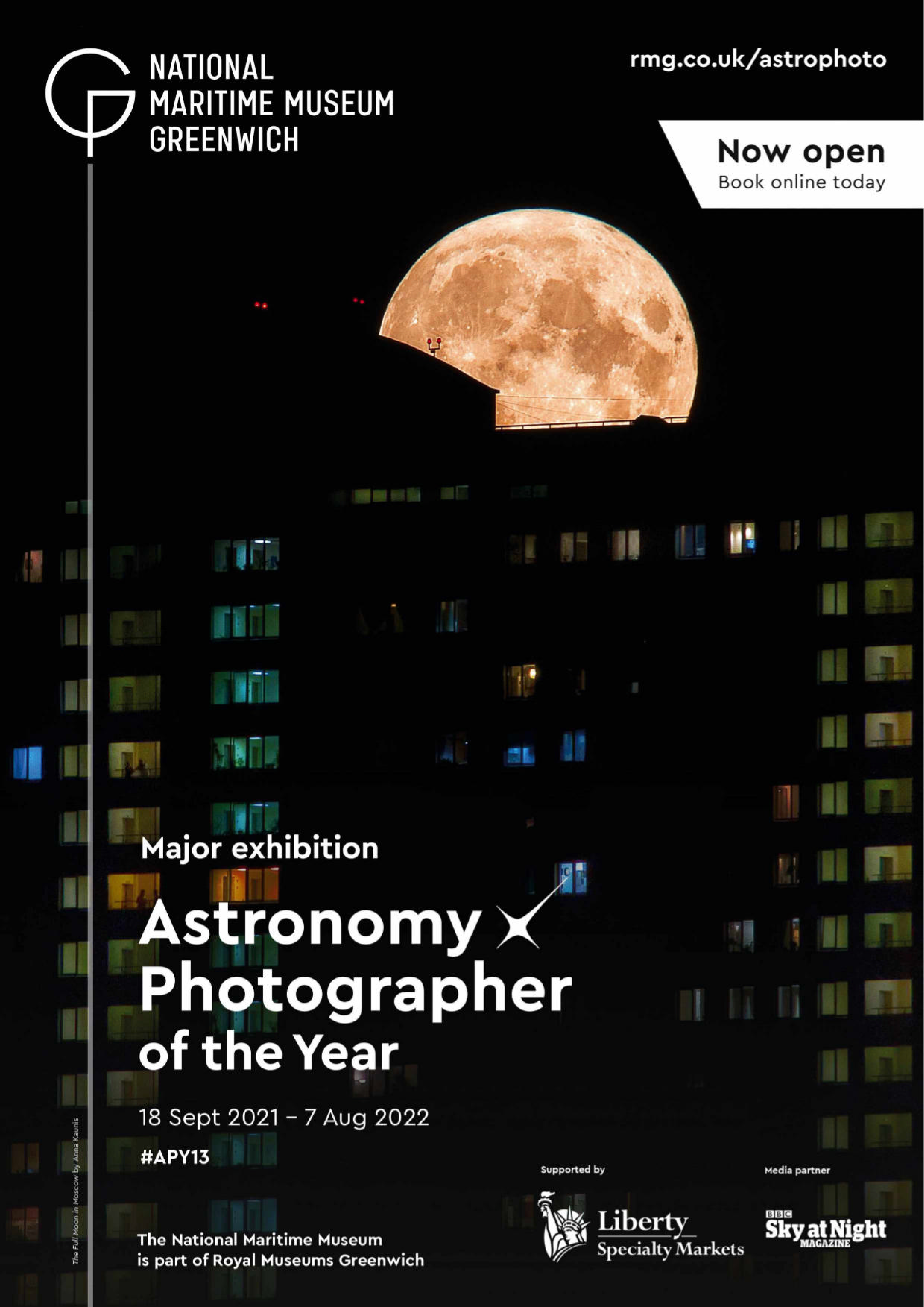
Weakened gravity?

There's also a chance that a satisfactory answer could provide a lesson on gravity. So far we've assumed that the balance is off because the compressibility of the nuclear matter isn't what we thought. But what if it's gravity that changes in this extreme situation? Maybe it doesn't have the power to shrink the star as much as we'd thought. That could open the door to seeing whether our current theory of gravity – Einstein's general theory of relativity – breaks down.

These questions are exactly why The Nuclear Physics from Multi-Messenger Mergers project was established. It's a five-year, $3.25 million (almost £2.5m) collaboration designed to study collisions between neutron stars. These violent events create gravitational waves that surge outwards at the speed of light. When they wash up on Earth they bring important information about the neutron stars that collided and the dense matter that they are made from. Answering these questions could tell us, once and for all, what is going on deep inside neutron stars and why J0740, in particular, seems to defy our current attempts to explain its existence.

When gravitational waves wash up on Earth they bring important information about the neutron stars that collided and the dense matter that they are made from

Colin Stuart (@skyponderer) is an astronomy author and speaker. Get a free e-book at **colinstuart.net/ebook**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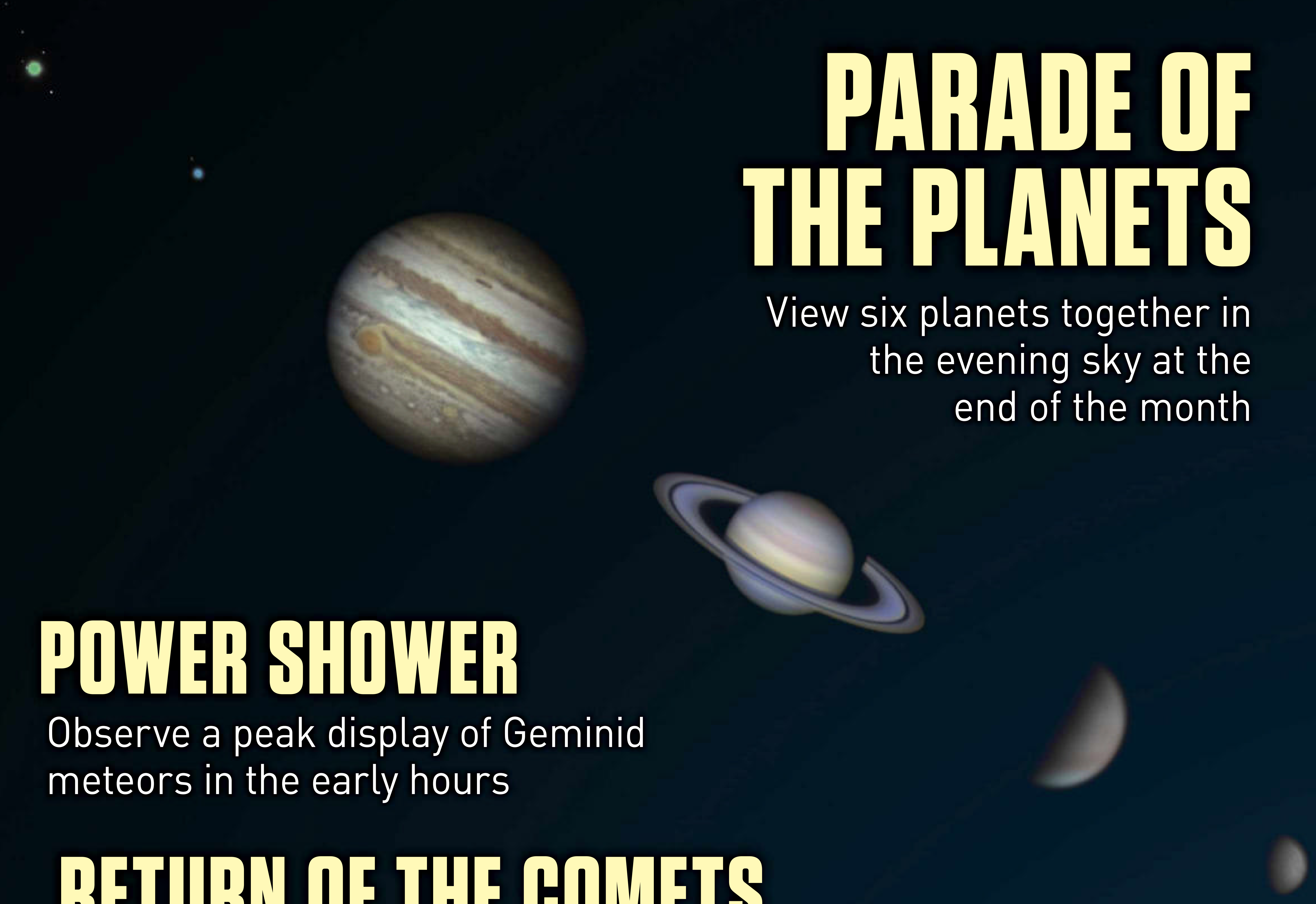
16-PAGE CENTRE PULLOUT

The Sky Guide

DECEMBER 2021



PETE LAWRENCE

PARADE OF THE PLANETS

View six planets together in the evening sky at the end of the month

POWER SHOWER

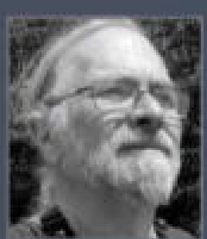
Observe a peak display of Geminid meteors in the early hours

RETURN OF THE COMETS

Catch Comet C/2021 A1 Leonard among December's icy visitors

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month…

- ✦ Occultation of the white supergiant Eta (η) Leonis
- ✦ Lunar clair-obscur effects, including the Eyes of Clavius
- ✦ Jupiter shadow transits

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

DECEMBER HIGHLIGHTS

Your guide to the night sky this month

Wednesday 1

With the Moon out of the way, this is a great time to enjoy our 'Deep-sky tour' on page 56. This month we're looking at objects in northern Orion.

Thursday 2

A gorgeous 5%-lit waning crescent Moon graces the morning sky, rising above the southeast horizon shortly before 05:30 UT, as seen from the centre of the UK. Wait just over an hour and Mars will also appear, shining at mag. +1.6.

Friday 3

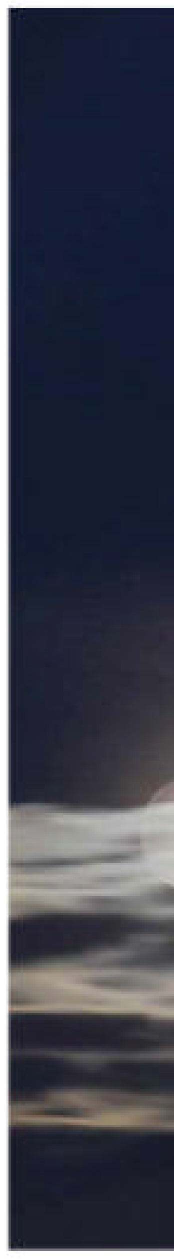
Rounding off an excellent year of thin Moon spotting opportunities, after Mars rises this morning at around 06:20 UT, a 1%-lit Moon appears about 30 minutes later. Look for the pair low above the southeast horizon.

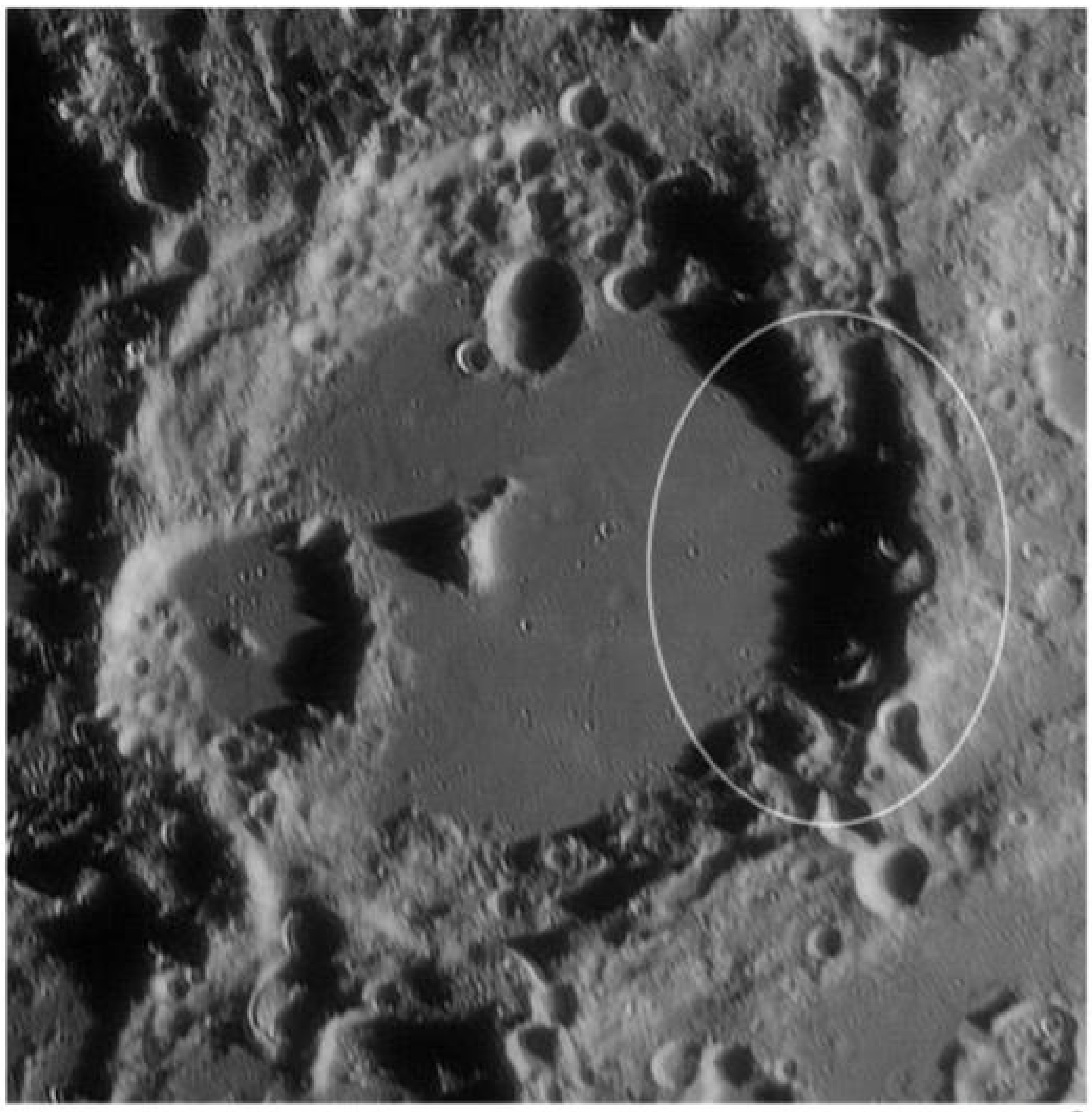
Tuesday 7

This evening a 16%-lit waxing crescent Moon sits south of the mid-point between mag. –4.6 Venus and mag. +0.9 Saturn. Venus, Saturn and mag. –2.1 Jupiter currently appear in a line in the evening sky, with Saturn in the middle.

Wednesday 8 ▶

This evening, the 22%-lit waxing lunar crescent sits south of the mid-point between Saturn and Jupiter.





◀ Saturday 11

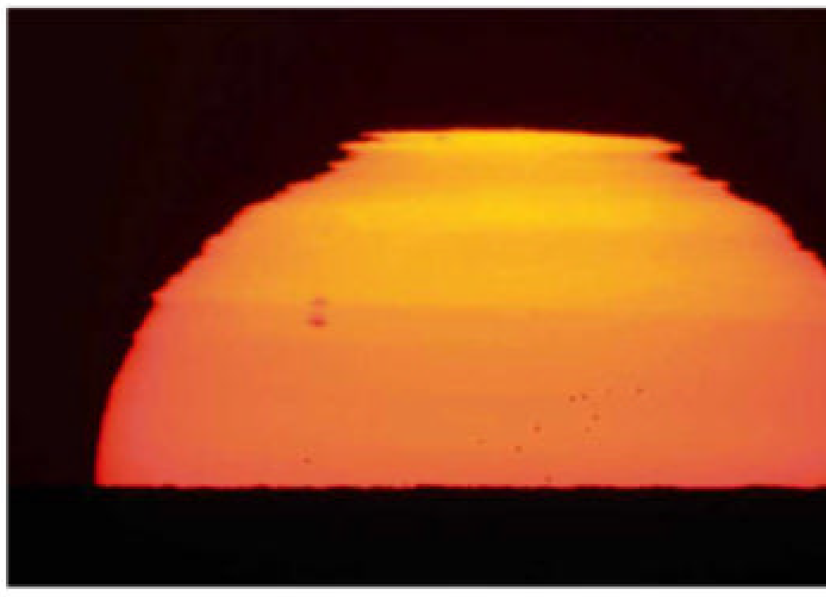
A medium to high power view of crater Albategnius around 20:30 UT will show that the shadow cast by its rim appears to reveal the profile of a face. This is the clair-obscur effect known as the Face in Albategnius.

Sunday 12

As the lunar dawn breaks over crater Clavius this evening, the outer rims of two of its inner craterlets catch the Sun's rays early to form the Eyes of Clavius clair-obscur effect, best seen at 22:20 UT.

Tuesday 21 ▶

At 15:59 UT the centre of the Sun's disc will reach its lowest position in the sky relative to the stars, an instant in time called the winter solstice in the Northern Hemisphere.



Family stargazing

Six planets are visible in the evening sky towards the month's end. With the aid of our 'All-sky chart' on page 50 and 'The Planets' on page 48, see how many your young observers can find. Jupiter and Saturn are the easiest; Mercury and Venus (page 48) need a low, flat southwest horizon. Take care that the Sun has set properly before looking. Uranus and Neptune (page 47) require binoculars. If you manage to see all six, pose the question – which one is missing from the line-up? The answer is Mars, which sits near the star Antares in the morning sky. **www.bbc.co.uk/cbeebies/shows/stargazing**

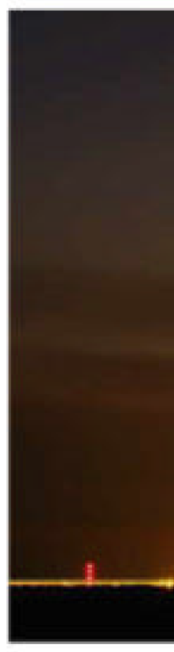
Friday 24

As the 78%-lit waning gibbous Moon passes its highest point in the morning sky due south, it occults Eta (η) Leonis. From the centre of the UK the star disappears at 04:16 UT, reappearing from behind the Moon's dark limb at 05:09 UT.

Monday 27

Over a flat southeast horizon, take a look about 07:00 UT. Mag. +1.5 Mars appears 4.5° from its rival in the sky, mag. +1.0 Antares (Alpha (α) Scorpii).

Callisto's shadow transits Jupiter, 12:35 UT to 16:40 UT.



PETE LAWRENCE X 7

Saturday ▶

4 If you can grab a view of mag. –4.6 Venus this evening, the planet is currently showing a 25% phase and appears 40 arcseconds across.

Monday

6 The Moon starts its parade of planets this evening. It's currently an 8%-lit waxing crescent located 5.8° from mag. –4.6 Venus, visible low to the southwest shortly after sunset.

Thursday

9 Shortly after sunset the 35%-lit waxing crescent Moon lies 6.7° southeast of bright Jupiter.

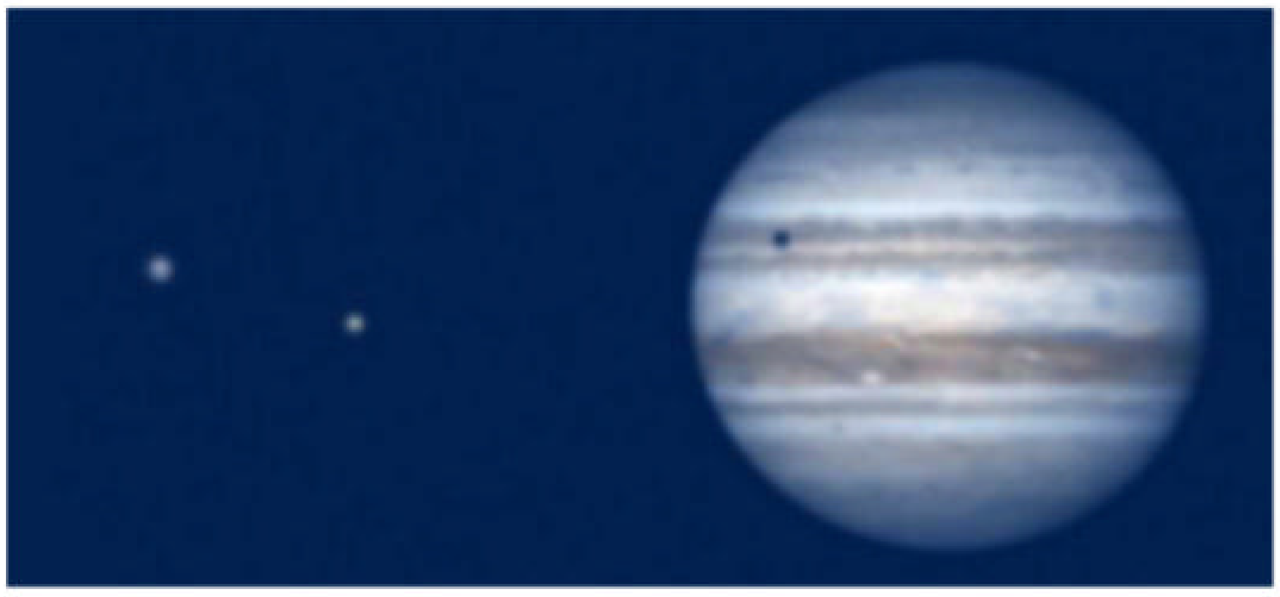
Monday

13 The Geminid meteor shower reaches peak activity around 07:00 UT on 14 December, making tonight and tomorrow night ideal times to look for its meteors. A 78%-lit waxing gibbous Moon sets after 03:00 UT on the 14th, leaving three hours of dark sky.

Wednesday ▶

22 The peak of the Ursid meteor shower occurs, but it's three days after full Moon, meaning the glare washes out the shower.

Ganymede's shadow crosses Jupiter. The event ends at 18:45 UT.



◀ Tuesday

28 Mercury and Venus are close above a flat southwest horizon, 40 minutes after sunset.

You can observe Mercury, Venus, Saturn, Jupiter, Neptune and Uranus this evening. See page 47 for details.

Friday

31 Mars remains near to its celestial contender, the red supergiant star Antares, literally the 'rival of Mars'. This morning, set against a brightening dawn sky, the two are joined by an 8%-lit waning crescent Moon.

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

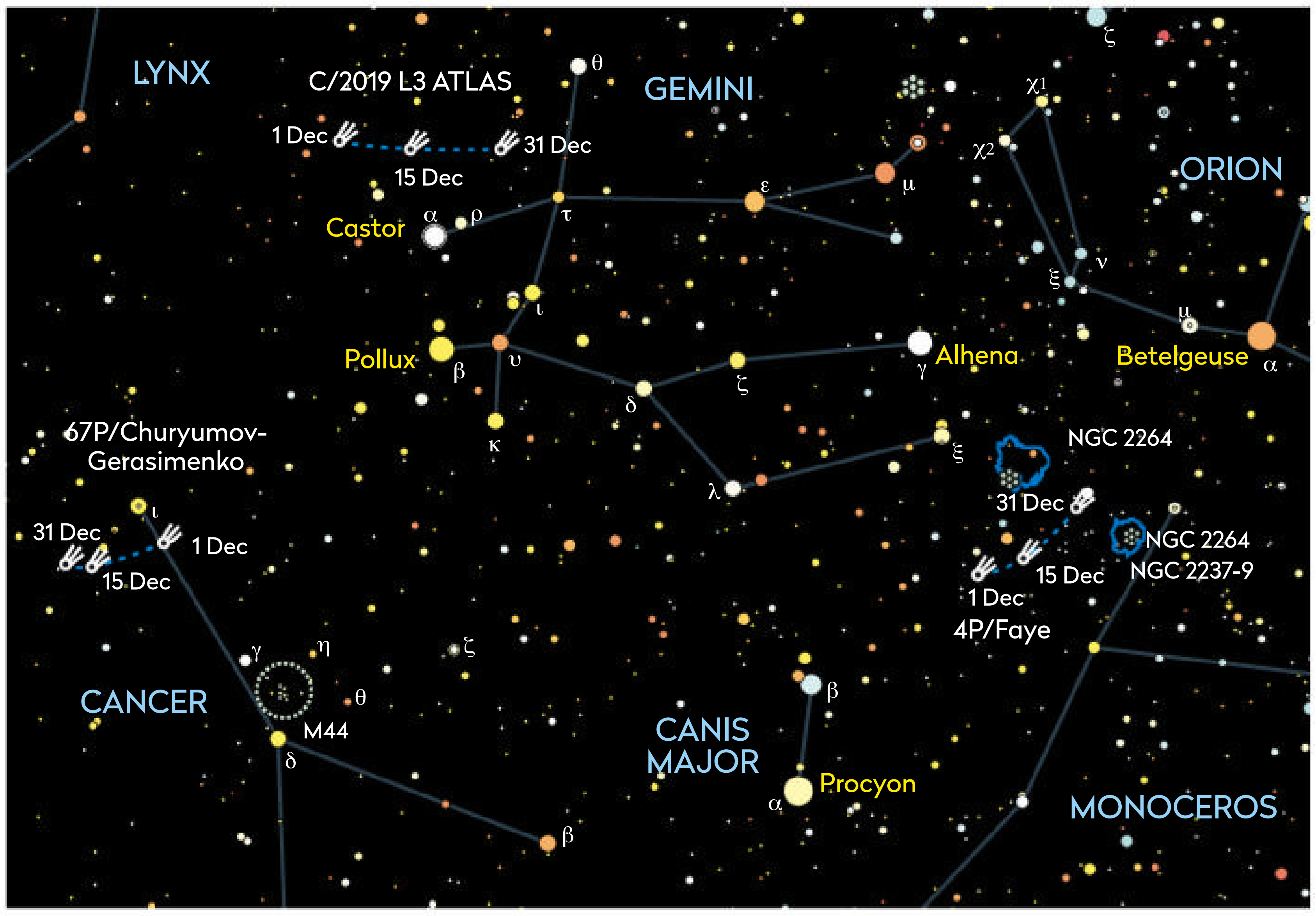
GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE
The top sights to observe or image this month

DON'T MISS

DECEMBER COMETS

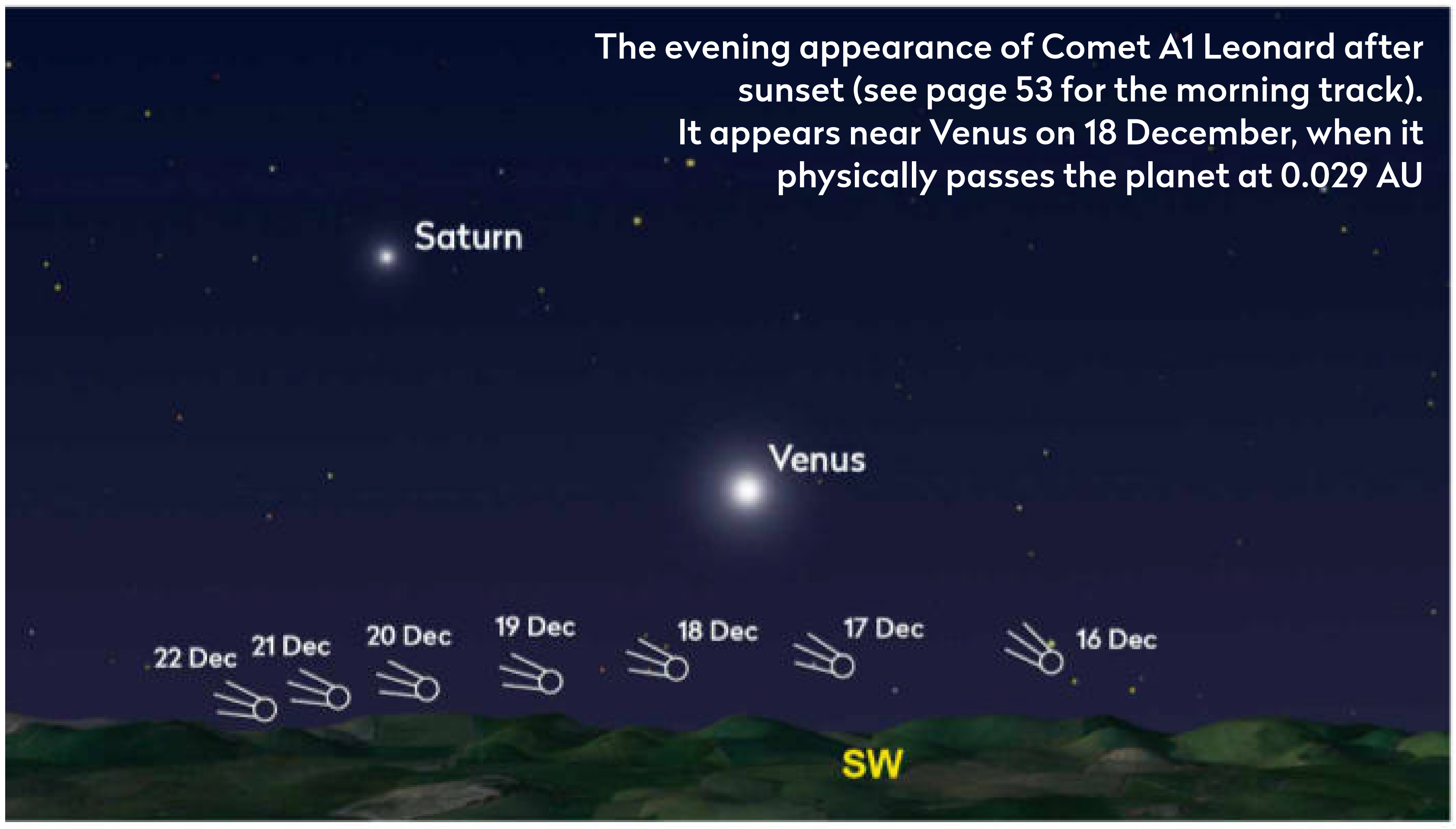
BEST TIME TO SEE: 1-16 December



▲ The month's tracks for C/2019 L3 Atlas, 67P Churyumov-Gerasimenko and 4P/Faye

There are three reasonably bright comets and one wild card in this month's sky. Comets 67P Churyumov-Gerasimenko, 4P/Faye and C/2019 L3 Atlas are all located in the general region centred on Gemini, highest around 00:30 UT on 1 December, 23:30 UT mid-month and 22:30 UT by the month's end.

67P is the periodic comet visited by the Rosetta spacecraft from 2014 to 2016. It reached perihelion on 2 November when it was brightest at mag. +10.7. During December, 67P fades from mag. +10.9 to +11.7. The comet is relatively easy to find as it never wanders far from mag. +4.0 Iota (ι) Cancri, staying within 5° of the star throughout December.



The evening appearance of Comet A1 Leonard after sunset (see page 53 for the morning track). It appears near Venus on 18 December, when it physically passes the planet at 0.029 AU

ALL PICTURES: PETE LAWRENCE

Periodic comet 4P/Faye reached perihelion on 8 September and like 67P is now fading. On 1 December it is predicted to be at mag. +11.9, not significantly dimmer than its mag. +11.5 perihelion peak. By the month's end, it will have dimmed to mag. +12.5. 4P/Faye follows a gently curving track to the west this month, in an area of sky about 9° to the south of Alhena (Gamma (ζ) Geminorum).

Comet C/2019 L3 Atlas is the brightest of the three, starting the month at mag. +9.9 and ending at mag. +9.7. Its December track starts conveniently 5° to the north of Castor (Alpha (α) Geminorum) and from there follows an almost linear path southwest, moving just 7° throughout the month. Actually, all three comets have relatively short paths this month making it both easier to keep track of these objects and photograph them.

At the start of 2021, newly discovered comet C/2021 A1 Leonard was announced. Excitingly this had the possibility of becoming bright during December and exceeding the threshold of naked-eye visibility. Current estimates have it near mag. +4.3 Beta (β) Comae Berenices on the 1st, shining at mag. +9.3. It's then expected to brighten to about seventh magnitude mid-month, an easy binocular object. An effect known as forward-scattering enhancement may boost its brightness so it becomes visible to the naked eye.

Forward-scattering enhancement may help A1 Leonard become visible to the naked eye between 10–16 December, peaking at mag. +4.0 around the 13th. The comet's sky location isn't that favourable from the UK. The best prospects will be during the mornings of 1–13 December. Its morning track is shown on page 53, while on this page we've shown how the comet moves relative to Venus in the evening sky. Unless the comet brightens more than expected, the evening appearance will probably go unnoticed from the UK due to low altitude.

Geminids 2021

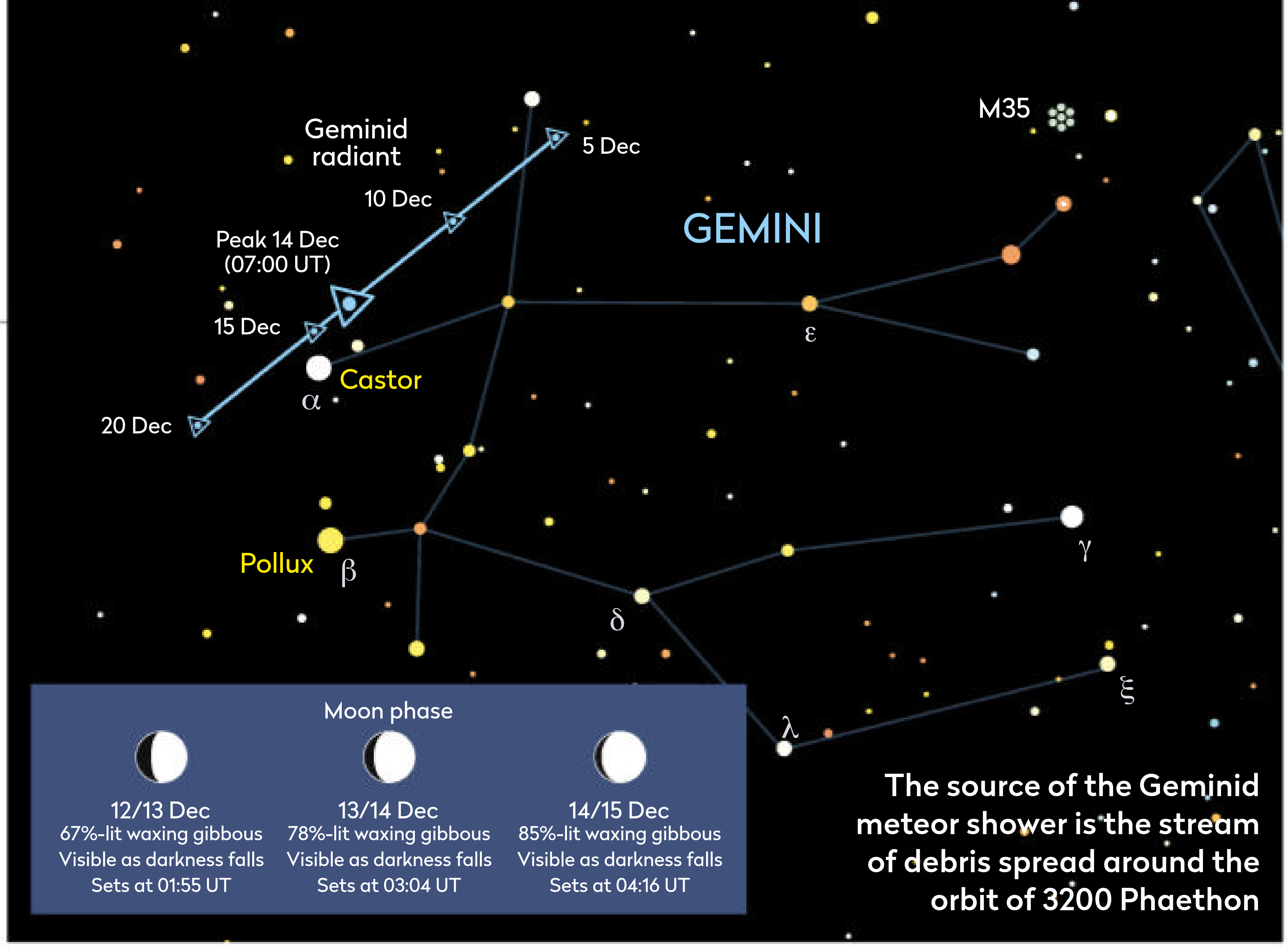
BEST TIME TO SEE: Early hours of 13, 14 and 15 December

The Geminid meteor shower is one of the favourite observing events for the year. As with any meteor shower, the shower's success is dictated by the phase of the Moon and the weather. There's not much we can do about the latter, except to move to a location where the clouds are less likely, but the Moon's phase is very predictable, as is its rise and set time.

The Geminid shower reaches its peak around 07:00 UT on 14 December making the nights of the 13/14 December and 14/15 December optimum for viewing. The Moon is in an advanced waxing phase around this time. 78% illuminated in a waxing gibbous phase on the evening of 13/14 December, it sets around 03:00 UT on the 14th. Although this isn't ideal, long dark December nights mean there are still around three hours of darkness left to enjoy what the shower has to deliver.

The Geminid shower has an excellent zenithal hourly rate (ZHR) of 140–150 meteors per hour. A medium entry speed for the meteoroids also makes Geminid trails easier to photograph. A bright event can look pretty spectacular.

The best observing advice to spot a Geminid this year will be to get some sleep on the night of 13/14 December, setting your alarm clock for a 02:00 UT wake up. Prepare yourself with warm clothing and perhaps a hot drink in a flask. A sun lounger or deck chair makes a great viewing platform as it allows you to watch in relative comfort. Aim to view the sky at an altitude of 60° or so. Any direction is fine, although bear in mind that trails will be shortest closer to the radiant and longest 90° from the radiant. Convention dictates that a good compromise is to look 40–50° from the radiant position, which is located near the star Castor (Alpha (α) Geminorum) in Gemini.



The source of the Geminid meteor shower is the stream of debris spread around the orbit of 3200 Phaethon

Seven planets at sunset

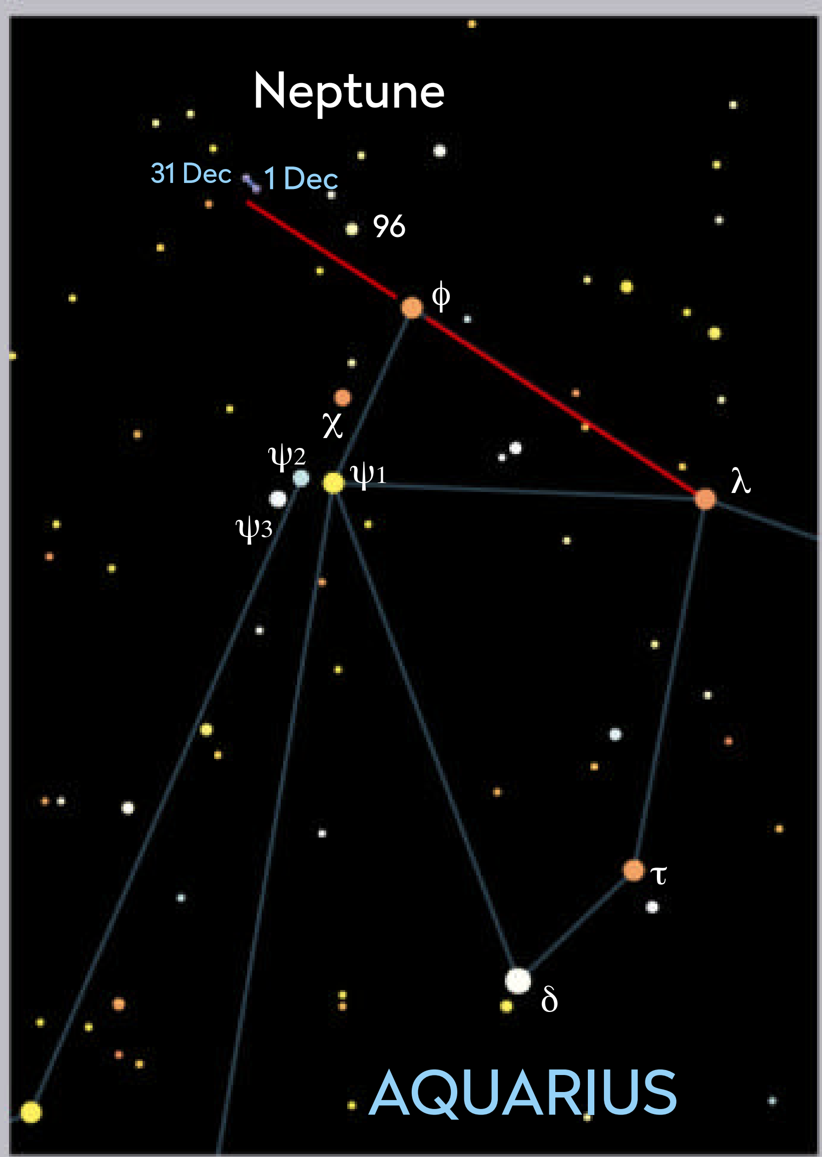
BEST TIME TO SEE: From 28 Dec to 3 Jan, 30 minutes after sunset

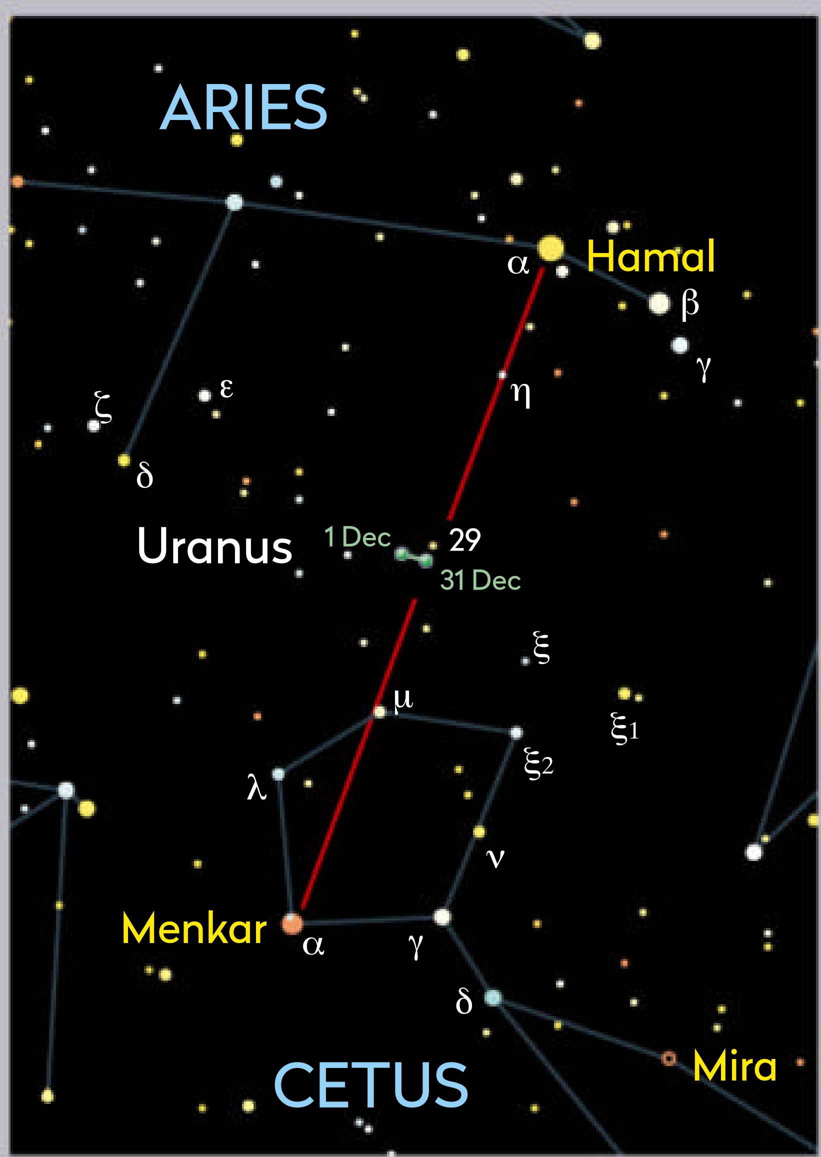
Seven planets are on view in the evening twilight sky towards the end of December. Given a good flat southwest horizon, mag. –4.3 Venus appears around 7˚ up, 30 minutes after sunset. On 28 December, mag. –0.7 Mercury can be seen 4.3˚ below Venus. Over the following evenings, Mercury maintains its brightness and improves in position compared to Venus (see page 48). Binoculars are the best bet for finding it, but make sure the Sun has set properly.

As Mercury and Venus approach the southwest horizon, look further east (up and left from the UK) to locate mag. –2.0 Jupiter. Midway between Venus and Jupiter lies dimmer mag. +0.9 Saturn.

True darkness occurs just after 18:00 UT and this is the time to look for Uranus and Neptune. Extend a line from mag. +2.0 Hamal (Alpha (α) Arietis) through mag. +5.2 Eta (η) Arietis for approximately three times again to locate a pair of sixth magnitude objects. The southern one is mag. +5.7 Uranus. Neptune is a binocular planet too. Shining at mag. +7.9, it's currently located 3.2˚ to the east-northeast of mag. +4.2 Phi (φ) Aquarii.

If you're wondering where the seventh planet is in this scenario, it's all around you of course – Earth! The only main planet currently absent from the evening sky is the morning planet Mars.





▲ **Use these locator charts to find Neptune (left) and Uranus (right). Jupiter and Saturn are viewable with the naked eye and you can find charts for Mercury and Venus on page 48**

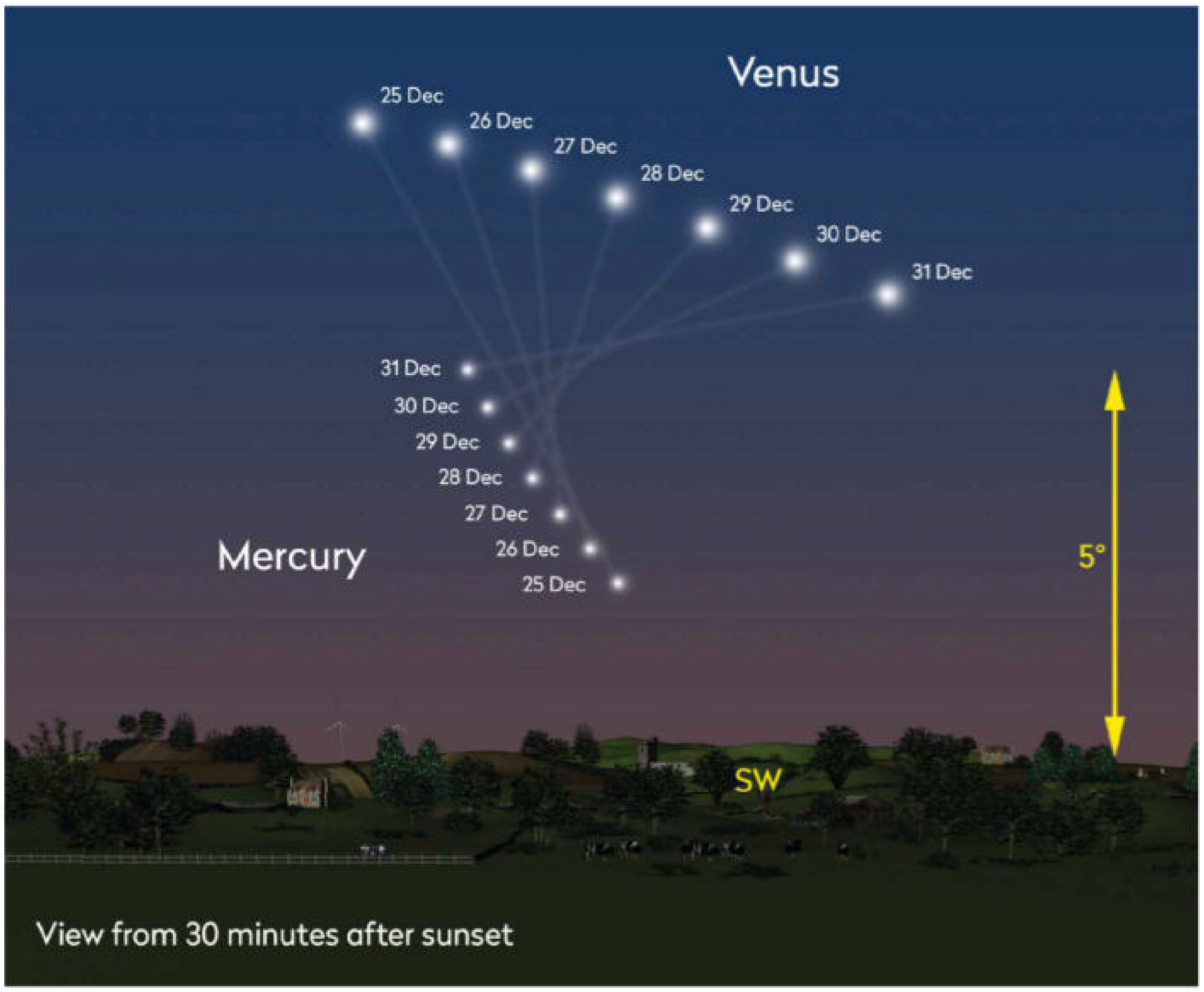
THE PLANETS

Our celestial neighbourhood in December

PICK OF THE MONTH

Mercury

Best time to see: 31 December, 30 minutes after sunset
Altitude: 5° (low)
Location: Sagittarius
Direction: Southwest
Features: Phase, surface shadings with larger instruments
Recommended equipment: 75mm, or larger



▲ **Mercury can be seen slowly approaching Venus in the evening twilight**

Although it's poorly placed at the start of December, the planet Mercury's position improves towards the end of the month, aided by that brilliant beacon of the twilight sky, Venus. On 19 December, Mercury sets around 35 minutes after the Sun and despite shining at mag. –0.7 on this date, will be a tricky object to see. Fortunately, this brightness is maintained for the rest of the month, and coupled with an increasing apparent separation from the Sun, it will become an easier target as we head towards the end of December.

Passing through the eastern part of the constellation of Sagittarius, the Archer, Mercury can be seen slowly approaching Venus in the evening twilight. On the 29th, both planets appear separated by 4.3°, Mercury being south of mag. –4.3 Venus on this date. Mercury sets about 1 hour and 15 minutes after the Sun on the 29th, so with a good flat southwest horizon, there's every chance of spotting the mag. –0.7 planet from approximately 30 minutes after sunset. By the 31st, although located 6.3° southeast of Venus, the orientation of both planets is such that they more-or-less level out and appear to set together on this date. Both planets set 1 hour and 20 minutes after the Sun on 31 December.

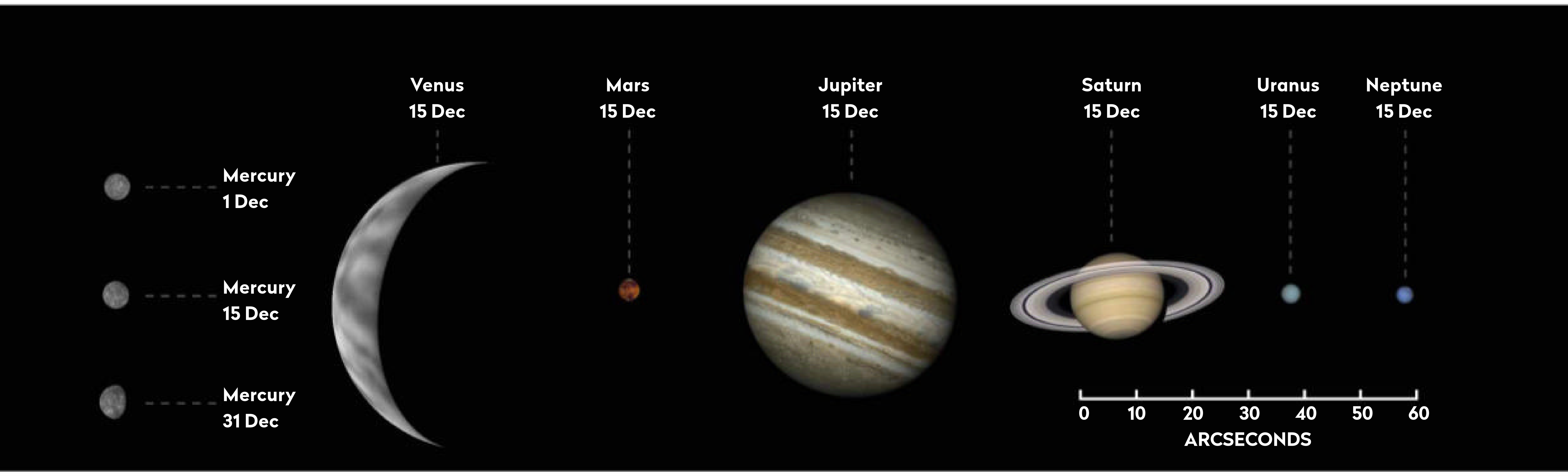
If you're able to get a telescope trained on Mercury, it will show as a tiny, almost fully lit disc mid-month, having a 97%-lit phase on 16 December. This drops to 80%-lit by 31 December. Over the same period the planet's apparent size increases from 4.9 to 5.8 arcseconds, still rather small by any measure.

Mercury reaches greatest eastern elongation next month, on 7 January. A thin, 5%-lit waxing crescent Moon lies near to it a few days earlier on 4 January.

PETE LAWRENCE X 3

The planets in December

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Venus

Best time to see: 1 December, from 30 minutes after sunset
Altitude: 10°
Location: Sagittarius
Direction: South-southwest
An evening planet, visible low above the south-southwest to southwest horizon at December's start. It sets 2 hours and 35 minutes after the Sun on the 1st, and 1 hour and 20 minutes after by the month's end. An 8%-lit waxing crescent Moon sits nearby on the 6th, and as a 16%-lit waxing crescent on the 7th. Venus appears 4.3° north-northeast of mag. –0.7 Mercury on the 29th, with both staying close for the rest of the month.

At mag. –4.7, Venus is at its brightest at December's start.

Mars

Best time to see: 31 December, 1 hour before sunrise
Altitude: 5° (low)
Location: Ophiuchus
Direction: Southeast
Mars makes a return to the morning sky. It's small through a scope's eyepiece, 4.0 arcseconds across by the month's end. A 1%-lit waning crescent Moon lies 4.5° east-southeast of mag. +1.6 Mars on the morning of the 3rd. On the 26th, Mars appears 4.6° north of mag. +1.0 Antares (Alpha (α) Scorpii). On the 31st Mars is revisited by the waning crescent Moon, this time 8%-lit. Mars rises two hours before the Sun on the 31st.

Jupiter

Best time to see: 1 December, 17:20 UT
Altitude: 23°
Location: Capricornus
Direction: South
Mag. –2.3 Jupiter reaches its highest position in the sky, 23° up, at December's start, under deep twilight conditions. By the month's end, the Sun is still up as Jupiter reaches this position, despite the planet setting 4.5 hours after the Sun.

A crescent Moon appears nearby on the evenings of the 8th (25%-lit waxing crescent) and 9th (35%-lit waxing crescent).

Saturn

Best time to see: 1 December from 17:00 UT
Altitude: 18°
Location: Capricornus
Direction: Just west of south
At the start of December, mag. +0.7 Saturn no longer appears above the southern horizon in darkness, only visible west of south as the evening twilight deepens. At the month's start, Saturn lies in the middle of a line formed by Jupiter to the east and Venus to the west.

Uranus

Best time to see: 1 December, 22:00 UT
Altitude: 52°
Location: Aries
Direction: South
Evening planet Uranus was at opposition last month and remains well placed during December, reaching a highest altitude of 52° in darkness all month. The mag. +5.7 planet sits 25 arcminutes south-southeast of mag. +6.0 29 Arietis on 29 December.

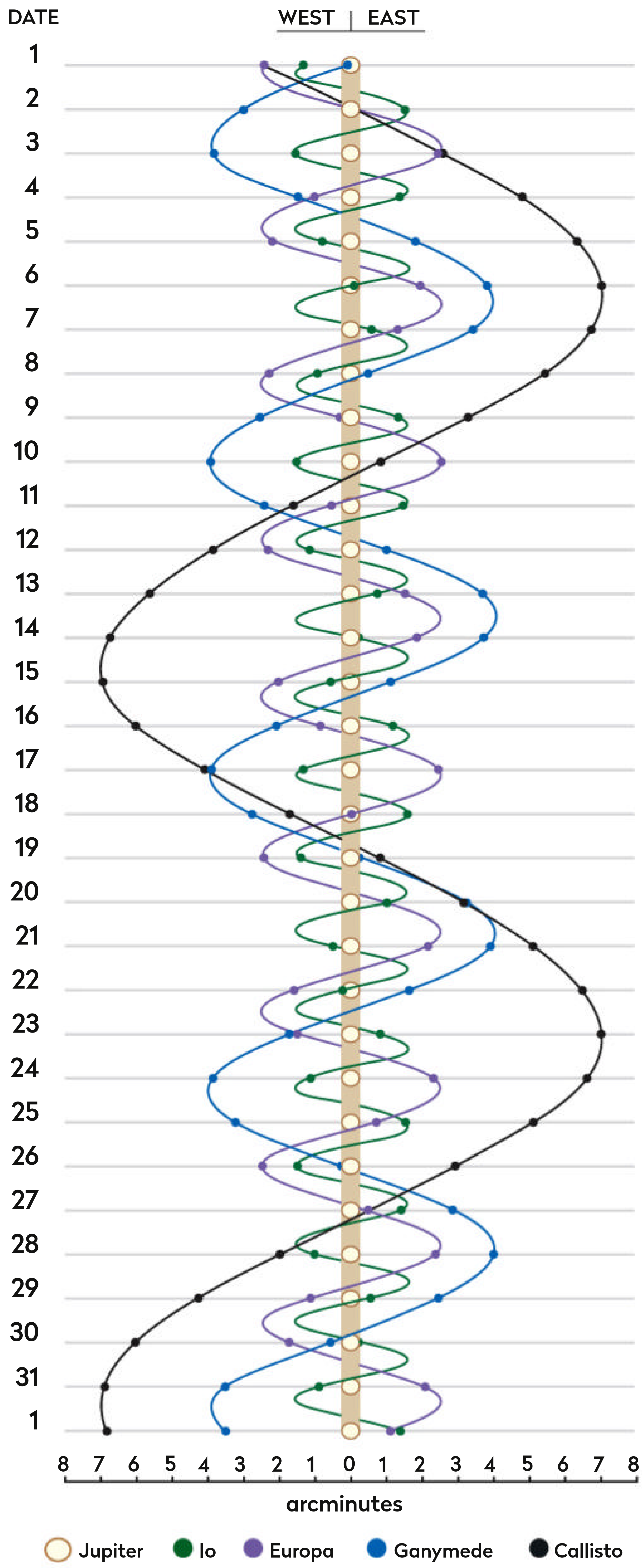
Neptune

Best time to see: 1 December, 19:00 UT
Altitude: 32°
Location: Aquarius
Direction: South
Mag. +7.9 Neptune's position declines this month, the evening planet only reaching a highest altitude of 32° in total darkness until the 15th.

More ONLINE
Print out observing forms for recording planetary events

JUPITER'S MOONS: DECEMBER

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – DECEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

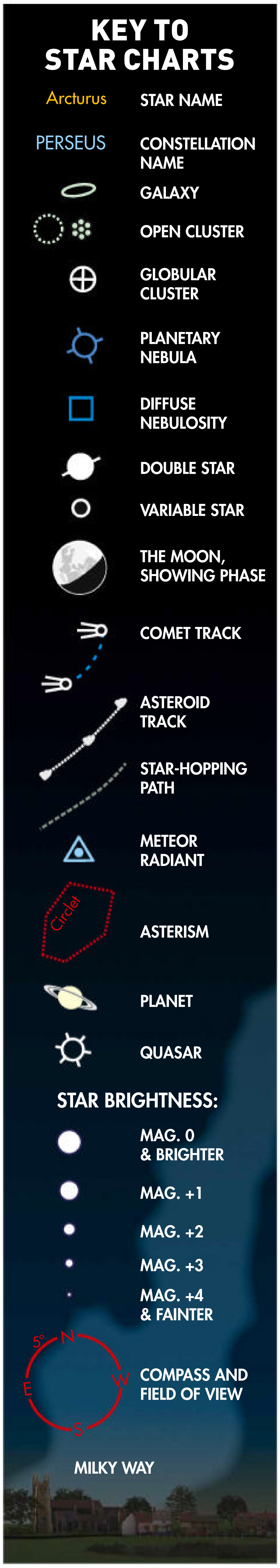


CHART: PETE LAWRENCE

When to use this chart

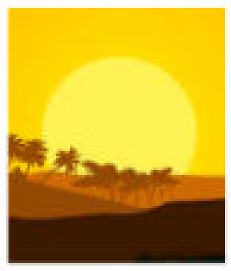
1 December at 00:00 UT
15 December at 23:00 UT
31 December at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in December*



Date	Sunrise	Sunset
1 Dec 2021	08:03 UT	15:55 UT
11 Dec 2021	08:16 UT	15:51 UT
21 Dec 2021	08:24 UT	15:53 UT
31 Dec 2021	08:26 UT	16:00 UT

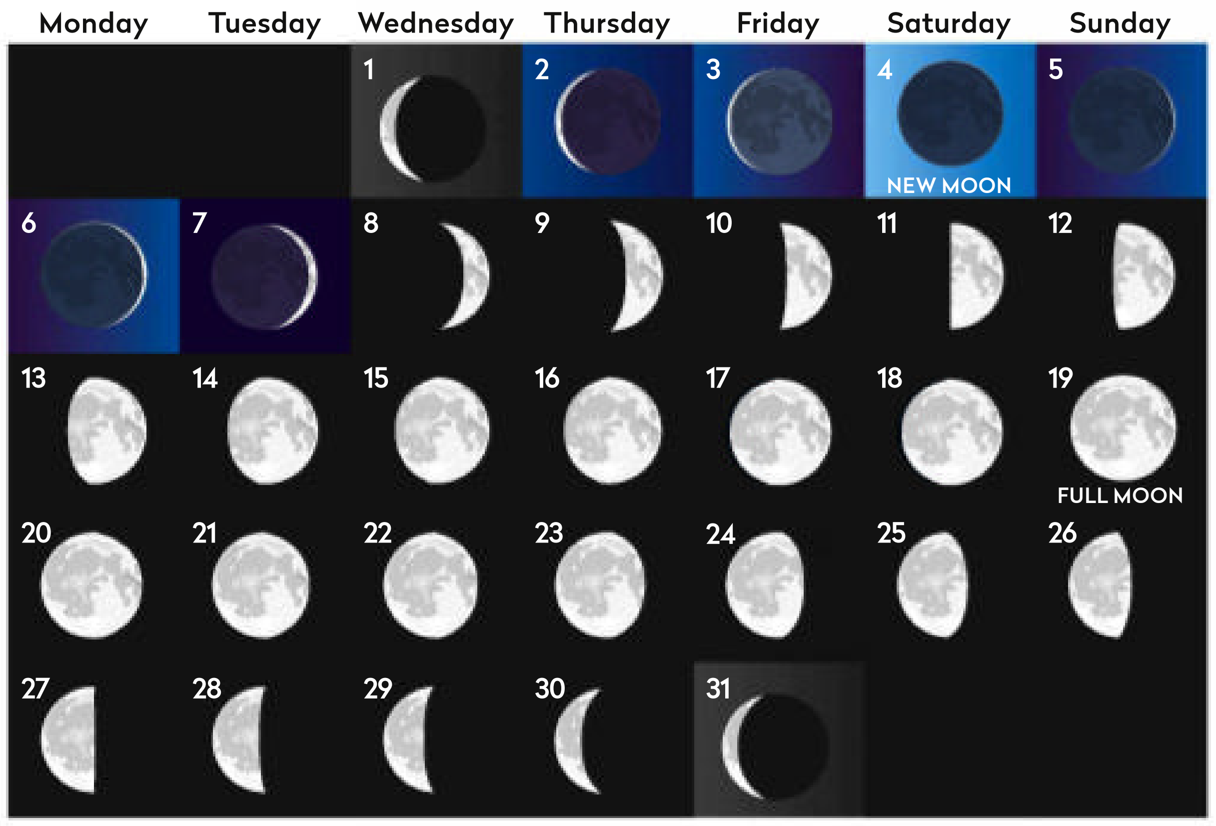
Moonrise in December*

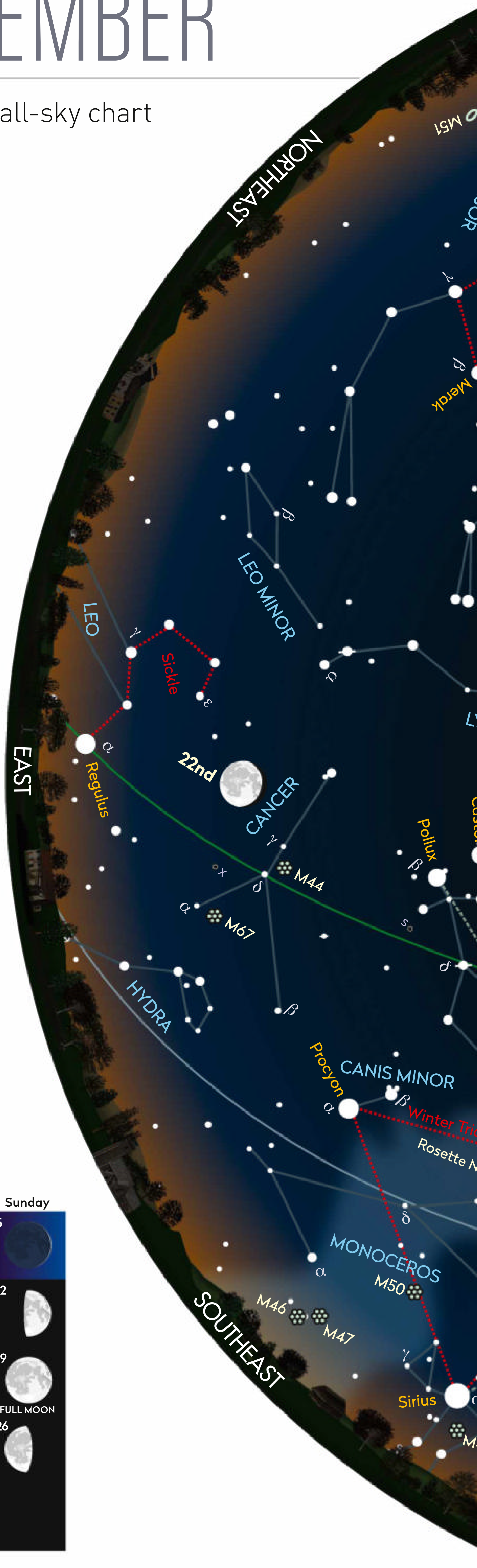
Moonrise times

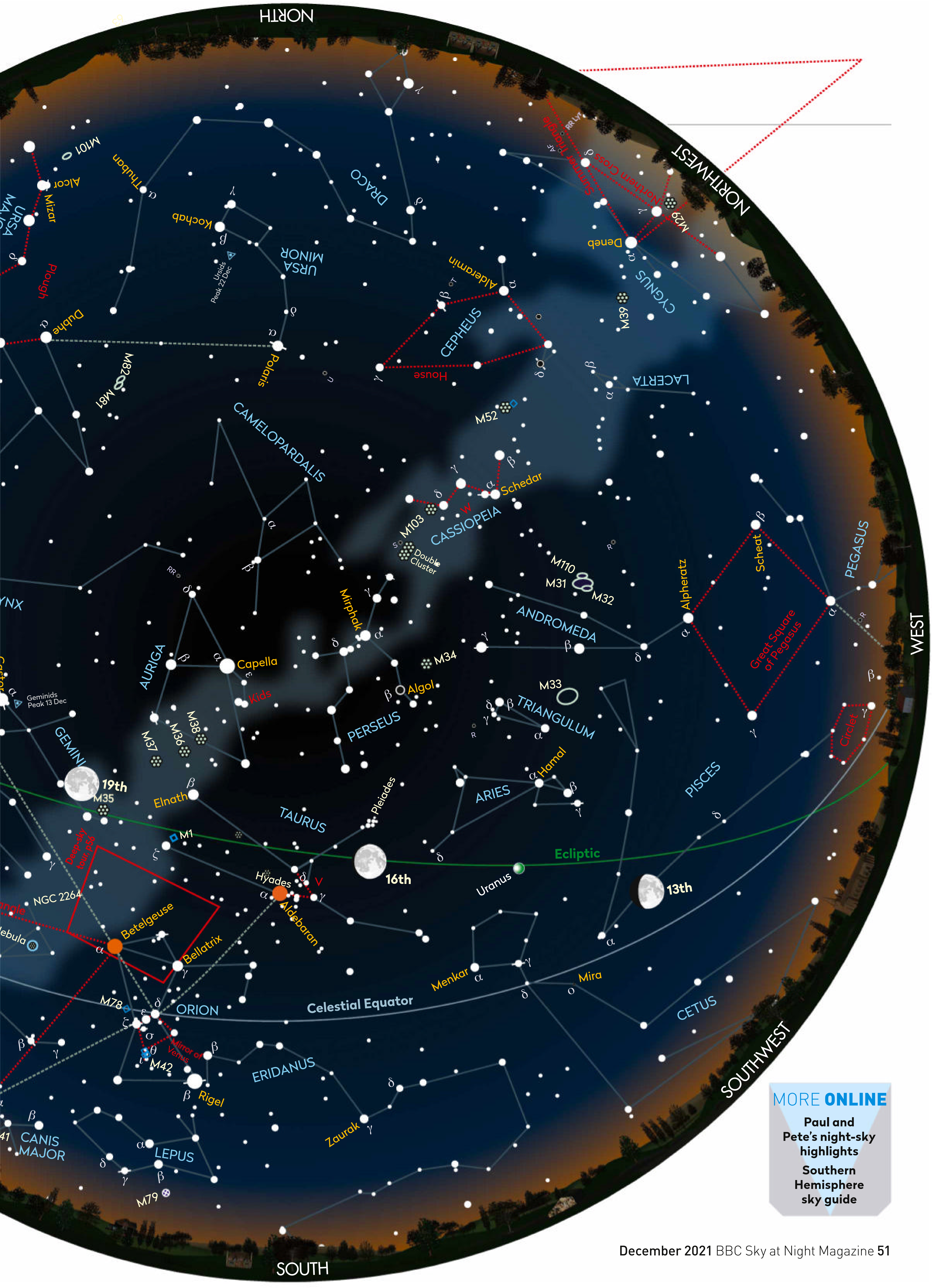
1 Dec 2021, 03:44 UT	17 Dec 2021, 14:38 UT
5 Dec 2021, 09:53 UT	21 Dec 2021, 17:38 UT
9 Dec 2021, 12:45 UT	25 Dec 2021, 22:39 UT
13 Dec 2021, 13:36 UT	29 Dec 2021, 02:44 UT

*Times correct for the centre of the UK

Lunar phases in December







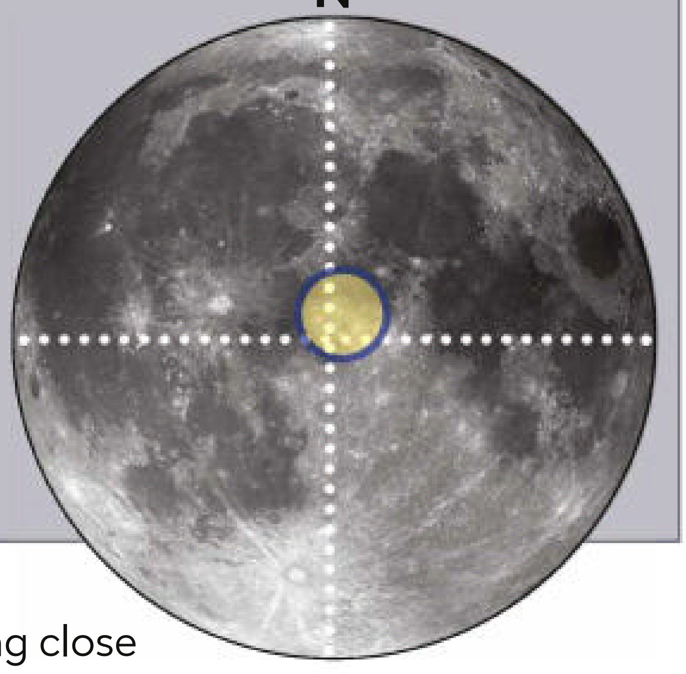
MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

Pallas

Type: Crater
Size: 50km
Longitude/Latitude: 1.7° W, 5.5° N
Age: Approximately 3.9 billion years
Best time to see: First quarter (11-12 December) or six days after full Moon (25-26 December)
Minimum equipment: 50mm refractor



Pallas is an ancient lunar crater appearing close to the centre of the Moon's disc as seen from Earth. The Moon's equivalent to Earth's prime meridian intersects the lunar equator in the dark 350km lava bay known as Sinus Medii ('central bay'). Fifty-kilometre Pallas is located in the rough highland region immediately north of Sinus Medii.

Pallas is ancient and battered. It sits between two prominent craters which couldn't be more apart in their appearance. To the north is bowl-shaped 18km **Bode**, a relatively young feature with a sharp, slightly non-circular crater rim. To the southeast is 58km **Murchison**, which is even more ancient than Pallas. Murchison's rim appears moderately broken south of Pallas and open to Sinus Medii in the south-southeast section. Pallas and Murchison are open to one another thanks to a small 5km gap in Pallas's eastern rim.

The rest of Pallas's rim is quite identifiable despite its battered appearance. An 11km interloper, **Pallas A**, interrupts the northwest rim section, easy to identify as it sits directly south of Bode. Pallas itself has a well-defined central mountain complex; a feature not present in either Bode or Murchison.

To the south of Pallas lies a hotch-potch of broken crater rims. Here lie the remains of 26km **Pallas E** and 18km **Pallas F**, partially rimmed features both with smooth floors. The small 3km craterlet **Pallas W** sits close to the inner eastern rim of **Pallas F**, a good test for a 200mm instrument.

Pallas B is a 4km crater located 47km to the southwest of Pallas's central mountains. It's a useful crater in that it marks the rough position of what could be a rather unique feature on the lunar surface, a tiny 1.5km crater known as **Stuart's craterlet**. This tiny feature is surrounded by a small ring of bright ejecta, something which you would normally associate with a young lunar feature. It is located near the southwest edge of the elevated region directly to the east of Pallas B.

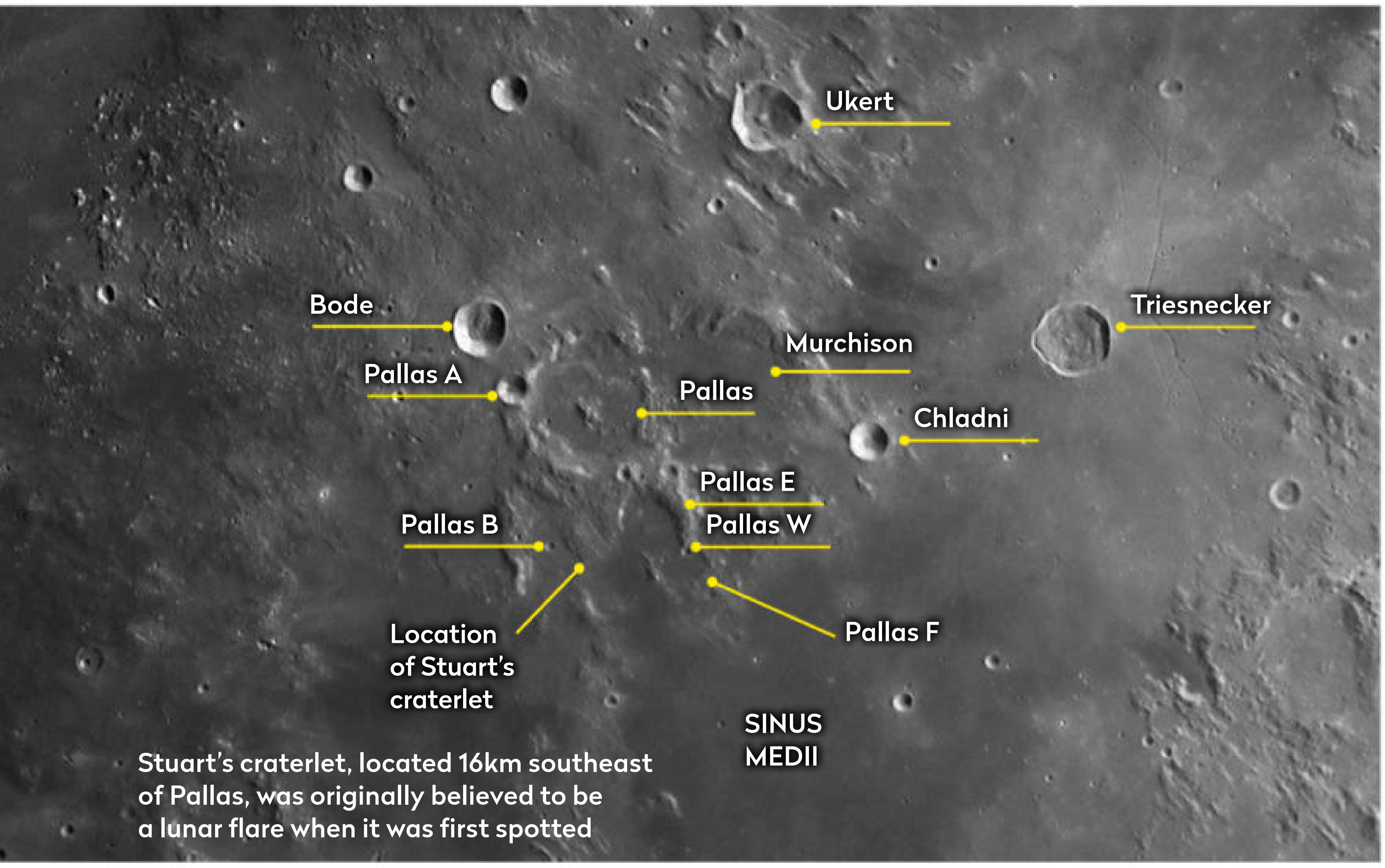
Pallas has a central mountain complex; a feature not present in Bode or Murchison

▼ **The crater Pallas is named after the 18th-century Prussian zoolologist and botanist Peter Simon Pallas, who worked in Russia**

The story of Stuart's craterlet is interesting and begins on 15 November 1953, when the physician and amateur astronomer Dr Leon H Stuart took a photograph of the Moon that appeared to show a bright event 16km to the southeast of Pallas. This was dismissed by professional astronomers, who suggested it was likely to be a local effect, perhaps a meteoroid vaporising in Earth's atmosphere.

It wasn't until many years later that Dr Bonnie Buratti saw Dr Stuart's image and began an investigation. The upshot of this research was the identification of a 1.5km crater within images taken by the Clementine spacecraft. This tiny feature appeared to match what would have been expected from the impact suggested by Dr Stuart's photograph and some now believe that Stuart had imaged an asteroid hitting the Moon's surface. Stuart's craterlet is pretty tiny, but not beyond the range of modern high-resolution imaging setups.

The 23km crater **Ukert** sits 112km to the northeast of Pallas. The ridges and elevated ranges around it are illuminated around the time of a first quarter Moon to produce the clair-obscur effect known as the 'Lunar V'.



Stuart's craterlet, located 16km southeast of Pallas, was originally believed to be a lunar flare when it was first spotted

PETE LAWRENCE X 3

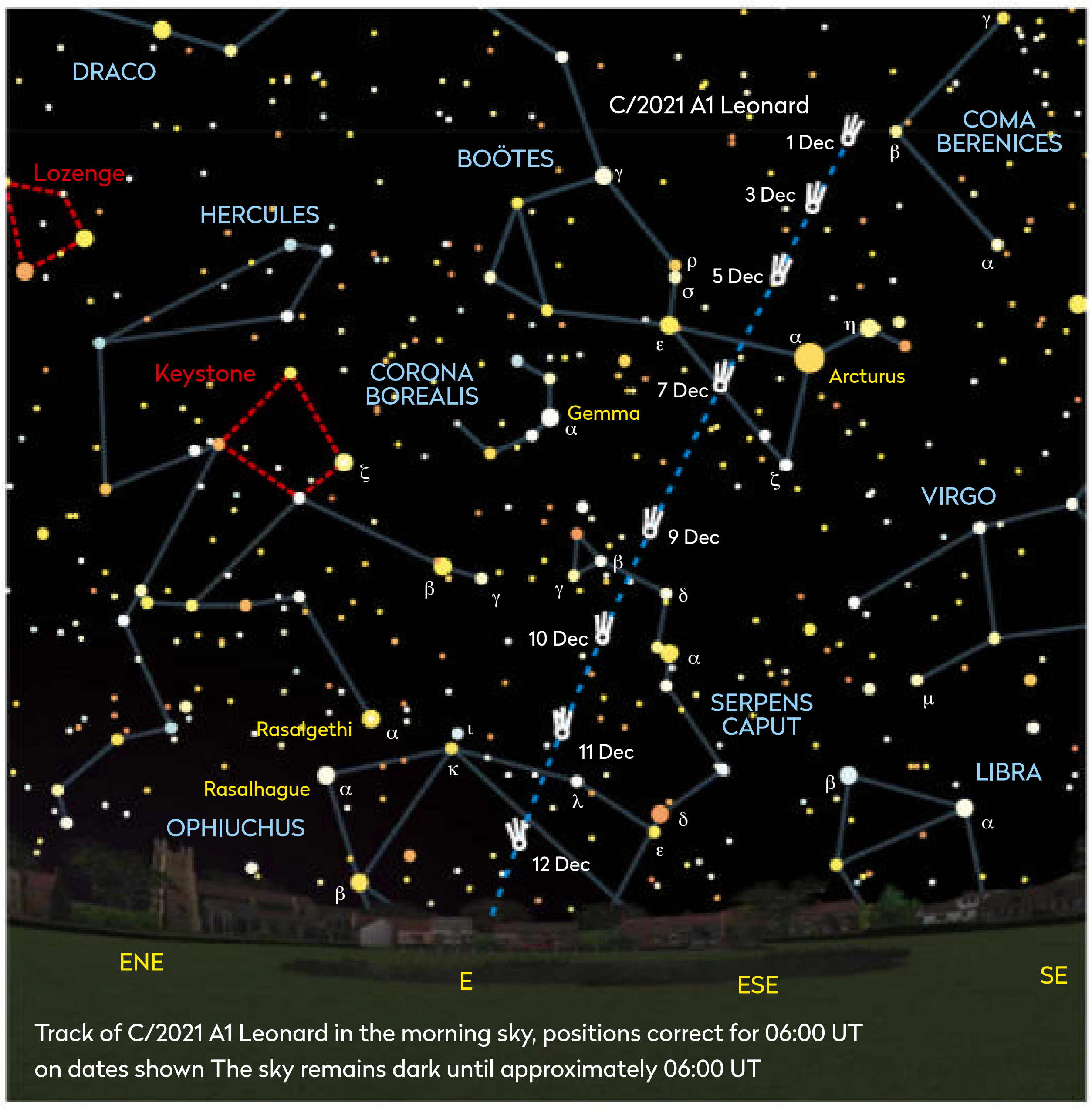
COMETS AND ASTEROIDS

Follow C/2021 A1 Leonard, which may reach naked-eye brightness this month

The possibility of a naked-eye comet is an exciting prospect. In 2020 we had C/2020 F3 Neowise, which gave us a major comet boost. At the start of 2021, predictions that comet C/2021 A1 Leonard might perform a similar trick produced a lot of excitement.

As time passed, A1 Leonard looked like it would fall short. Initially expected to be around the mag. +6.8 mark on 1 December, revised estimates now have it at around mag. +9.2. It won't be the easiest of comets to locate either, appearing low in the morning sky. Following the latest brightness curve, A1 Leonard will only reach a peak magnitude of around mag. +6.8 on the 13th, which places it below naked-eye threshold and within binocular range.

However, there's still hope for cometary redemption due to an effect known as forward-scattering enhancement. This occurs when the particles associated with the comet reflect sunlight towards the observer, so increasing the apparent brightness of the comet. The Sun-comet-Earth geometry needs to be correct for this to happen, but during December this is the case. The effect is predicted to kick in from 9–20 December, giving A1 Leonard an extra brightness boost that may tip it above the naked-eye threshold, maybe elevating it to fourth magnitude around the 13th.



▲ **Comet A1 Leonard's path during December's first half. See page 46 for the comet's evening track, which is visible later this month**

STAR OF THE MONTH

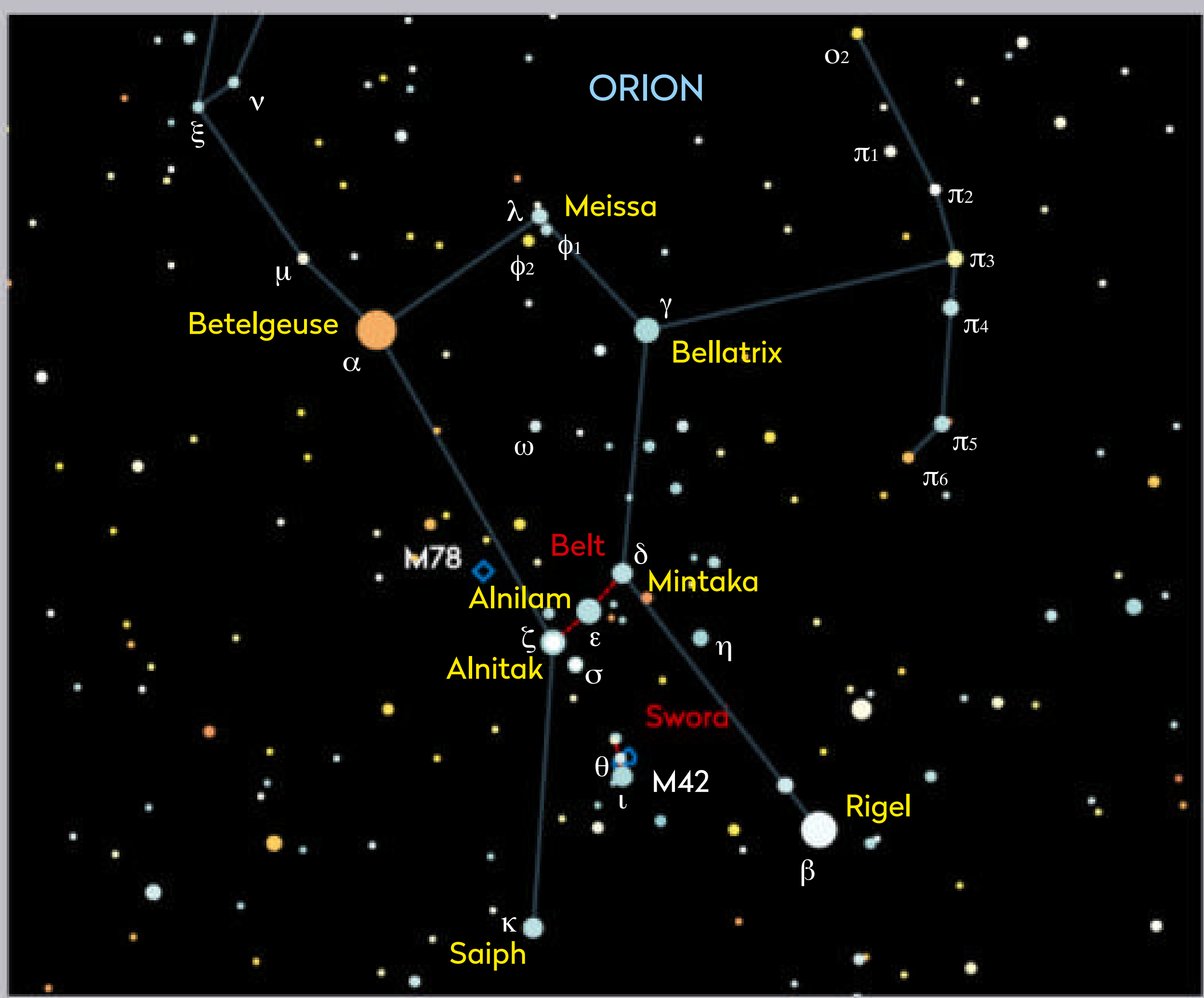
Spot Mintaka at the top of Orion's Belt

Mintaka (Delta (δ) Orionis) is easy to find. Shining at mag. +2.3, it marks the northwest end of Orion's Belt, the star's name deriving from the Arabic for 'belt'. Sitting 17 arcminutes south of the celestial equator, Mintaka hides a great deal of complexity. Observations made by Johannes Franz Hartmann in 1904, using photographs taken at the Potsdam Observatory in Germany, showed Mintaka was a spectroscopic binary. A spectroscopic binary shows periodic movement within its component star's spectral lines. Hartmann noticed the Calcium-K line at 393.34 nanometres didn't show the same periodicity as the Mintakan system and from this he deduced there must be a calcium cloud between us and the star. This was the first detection of what's known as the interstellar medium.

Mintaka is a complex multiple star, comprising a mag. +6.8 star 52 arcseconds to the north of the primary and a far fainter 14th magnitude star in between. The mag. +2.3 primary is designated A, the 14th magnitude star is B and the mag. +6.8 star C.

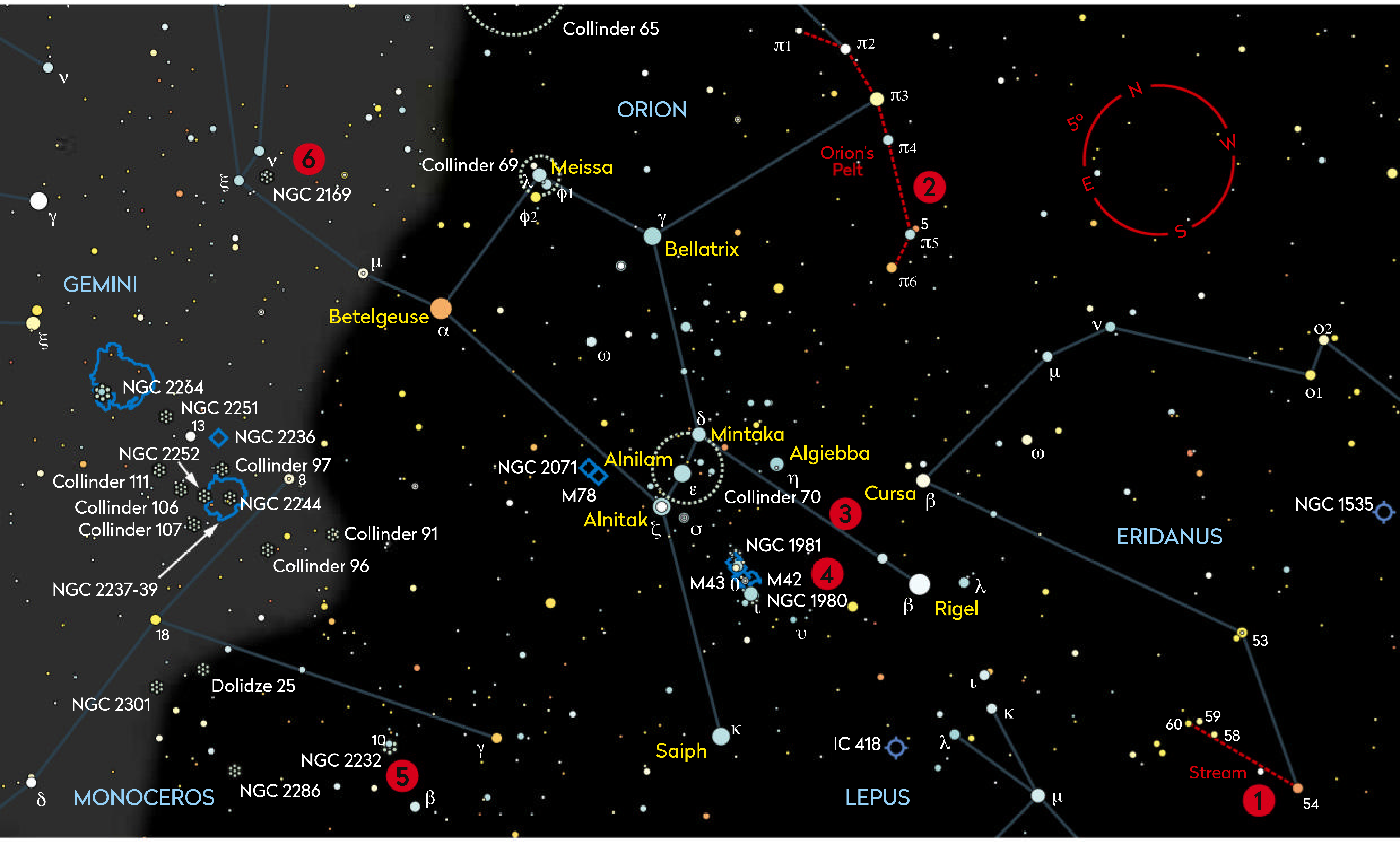
Delta (δ) Orionis A is the spectroscopic binary, an O9.5 II giant (Aa1) and B1 V main sequence star (Aa2) in a 5.73-day orbit. A B0 IV subgiant (Ab) sits 0.26 arcseconds from the spectroscopic pair. The 14th magnitude companion (B) is a cool star, about 70 per cent the size of our Sun and around 40 per cent as luminous. The seventh magnitude companion (C) is another spectroscopic binary comprising an A-type primary and B-type companion in a 30-day orbit.

▼ **There's far more to the multiple star Mintaka than meets the naked eye**



BINOCULAR TOUR With Steve Tonkin

Locate this month's selection of wide-field targets in and around Orion, the Hunter



PETE LAWRENCE X 3

1. The Stream

10x 50 Follow a line from Mintaka (Delta (δ) Orionis) through Rigel (Beta (β) Orionis) the same distance further on, to the most northerly of a colourful string of mostly 5th and 6th magnitude stars running down to the southwest. Note the colour gradation from orange 60 Eridani at the top of the chain, through yellow 59 and 58 Eridani, down to a fainter white star – then an abrupt change to the reddish 54 Eridani at the end. ☐ **SEEN IT**

2. Orion's Pelt

10x 50 The Pi (π) Orionis stars were traditionally depicted as an animal hide. They stretch over 9° of sky, so you will have to pan along it to see it all, but it is worth it as binoculars bring out the star colours. They range from white Pi^1 (π^1) and Pi^2 (π^2) Orionis, through yellow Pi^3 (π^3), down to blue Pi^4 (π^4) and Pi^5 (π^5), which contrasts well with the ruddy 5 Orionis and orange Pi^6 (π^6) Orionis. ☐ **SEEN IT**

3. Collinder 70

10x 50 Collinder 70 is the cluster nearly everybody has seen, but hardly anyone knows: it is the huge oval-shaped group of mostly blue-white stars surrounding Orion's Belt. On a clear night, you should be able to see about 70 stars. Can you see the swan whose S-shaped neck weaves its way down between Alnilam (Epsilon (ε) Orionis) and Mintaka, then rises up as it's wing between Alnilam and Alnitak (Zeta (ζ) Orionis)? ☐ **SEEN IT**

4. M42

15x 70 You can see the Orion Nebula, M42, with your naked eye as the central 'star' of Orion's Sword. Although it is a lovely object in binoculars of any size, especially in a dark transparent sky, use the biggest you have to help you tease out more detail. This showpiece of the winter skies is a star-forming region about 12 lightyears across and it will reveal more of itself the longer you gaze at it. ☐ **SEEN IT**

5. NGC 2232

10x 50 Start at Beta (β) Monocerotis, and navigate a little more than 2° north of it to a small fuzzy patch, that you may be able to see without binoculars. Binoculars reveal two distinct wedge-shaped groups of stars, with the two brightest stars (10 Monocerotis and 9 Monocerotis), each at the tip of a wedge. On a good night you should be able to count about 20 stars in 10x50s. ☐ **SEEN IT**

6. The 37 Cluster

15x 70 Take a line from Alnitak to Betelgeuse (Alpha (α) Orionis) and extend it 8° northwards to a pair of white stars, Nu (ν) and Xi (ξ) Orionis. Go back ½° towards Betelgeuse and you will find a rectangular cluster of stars, NGC 2169, with a void in the middle. If you mount them, 15x70 binoculars will show you that the brighter stars make a number '37'. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

THE SKY GUIDE CHALLENGE

Locate and image three variable nebulae to see how they change over time

Not all stars are constant in brightness, with many appearing to vary in output over time. Observing variable stars is a fulfilling and immensely important part of amateur astronomy, especially if you have the opportunity to do it regularly. Long-term observations reveal just how they change with time and give vital information about the nature of the variability. However, it's not just stars that vary in brightness, as some nebulae do it too and we've picked three for you to track down and observe for this month's 'Sky Guide Challenge'.

Variable nebulae are reflection nebulae which appear to change in brightness due to changes in the star that is illuminating them, or that star's environment. There are three primary examples that are visible in the Northern Hemisphere: McNeil's Nebula, Hind's Variable Nebula, NGC 1555 and Hubble's Variable Nebula, NGC 2261.

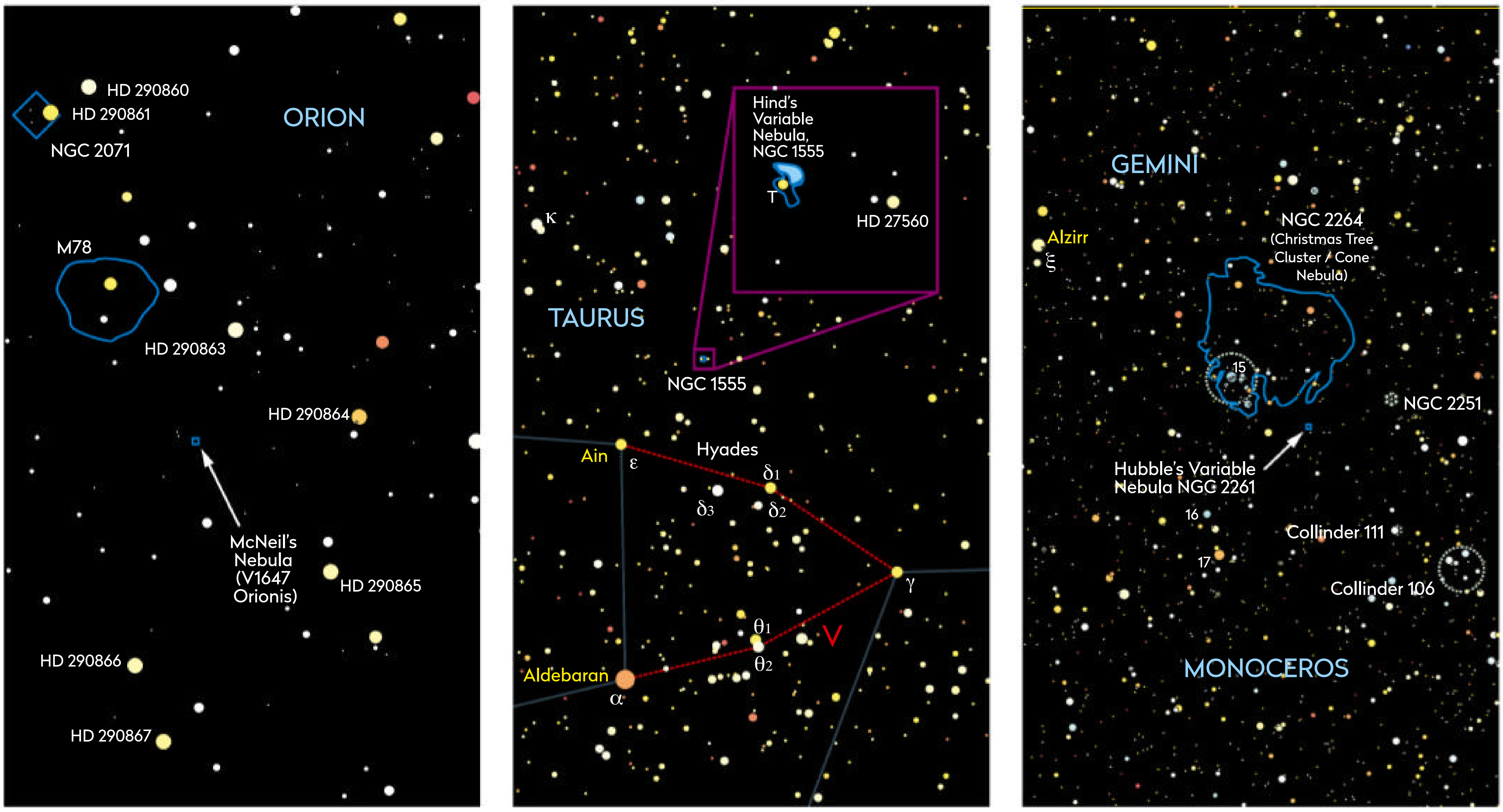
McNeil's Nebula, located in the constellation of Orion, the Hunter is a fairly recent discovery, having been identified as variable back in January 2004 when it was discovered by Kentucky-based amateur astronomer Jay McNeil from his back garden. It's associated with the variable star V1647 Orionis and is located 16 arcminutes south-southwest of the refection nebula M78. Around 15th magnitude, McNeil's Nebula is best suited for observation with large instruments or deep-sky imaging setups. Interestingly, back in 2018 the nebula disappeared completely and observing its reappearance (if this eventually occurs) is especially important.

Hind's Variable Nebula, NGC 1555, is located in the constellation of Taurus, the Bull and it was discovered in 1852 by English astronomer John Russell Hind. It is associated with the young variable star T Tauri. The star appears close to the Hyades open cluster, M25, but in reality is more distant. It's an easier object than McNeil's Nebula with an average magnitude of +9.6. Visually it appears as a faint arc near T Tauri and this is where the challenge comes in, because the star's glare makes it difficult to see. T Tauri is estimated to be around one million years old and varies in brightness between mag. +8.5 and mag. +13.5.

Hubble's Variable Nebula, NGC 2261, is a triangular-shaped region of nebulosity in the constellation of Monoceros, the Unicorn, illuminated by R Monocerotis. It was discovered by the US astronomer Edwin Hubble in 1949. With an average brightness around ninth magnitude, this is a fascinating object. Its variability is believed to arise when dense clouds of dust near R Monocerotis create shadows that pass across the nebula. The nebula appears around 2 arcminutes across.

Astro imaging is a good way to create an observational library of these objects. If you take images of each one over the course of many months – and eventually years – you will find that animating the results will reveal how amazing these objects are and how their appearances alter. In the case of the disappearing McNeil's Nebula, the process of determining how long it takes for the nebula to reappear is especially important.

All three objects are well placed at this time of year, so why not add them to your regular observing run? Your observations may help decode exactly what makes these nebulae tick.



▲ **Can you locate and image three primary examples of variable nebulae? The targets are NcNeil's Nebula (left), which is associated with the star V1647 Orionis; the Hind's Variable Nebula, NGC 1555 (middle), near T Tauri; and Hubble's Variable Nebula, NGC 2261 (right)**

DEEP-SKY TOUR

This month's tour visits objects in Taurus, some familiar and others less so

1 Collinder 69

Orion's head is marked by mag. +3.4 Meissa (Lambda (λ) Orionis). This marks the northern vertex of a small naked-eye triangle, together with mag. +4.4 Phi^1 (φ^1) Orionis and mag. +4.1 Phi^2 (φ^2) Orionis. A small scope at low power shows numerous fainter stars in the region, many belonging to cluster Collinder 69. Look out for the attractive line of seventh magnitude stars running south of Meissa.

Telescopes over 250mm may detect faint nebulosity around the cluster. This is Sharpless 2-264, an object made easier to see with an Oxygen (OIII) filter. It occupies a roughly circular area 6.5˚ across, centred on Meissa and has low surface brightness, with the brightest part west of Meissa. Long exposure images reveal the Angel Fish Nebula; a pink emission nebula that resembles a sideways-on fish. ☐ **SEEN IT**

2 NGC 2022

Our next object appears within the boundary of Sharpless 2-264, 1.9˚ east-southeast of Meissa. Here lies the brightest planetary nebula in Orion, NGC 2022, which isn't saying much as it shines with an integrated magnitude of +12.4! It has an apparent diameter of 20 arcseconds, with small scopes revealing a star-like object at low magnification. Upping the power won't show detail, but should reveal the elliptical shape of this planetary.

Larger instruments show a grey ellipse with a darker region in the centre that creates the appearance of a ring. The central star has a mag. +14.9 and requires at least 400mm of aperture to see properly. ☐ **SEEN IT**

3 Abell 12

The Abell catalogue of planetary nebulae lists 86 objects, many of which are faint and require large scopes. Abell 12 adds to the challenge as it's located near Mu (μ) Orionis. Mu shines at mag. +4.1 while the integrated magnitude of Abell 12 is +13.9, over 8,000 times dimmer than the star. Abell 12 is around 0.5 arcminutes from Mu and falls within its visual glare, making the planetary difficult to see, even with a large instrument. Nicknamed the 'hidden planetary', the trick is to employ a large aperture and an OIII filter. ☐ **SEEN IT**

▲ **The stars in open cluster NGC 2169 are likened to a number '37' and a shopping trolley**

GÜNTER KERSCHHUBER/CCDGUIDE.COM, CHART BY PETE LAWRENCE

4 NGC 2141

Open cluster NGC 2141 sits 0.8˚ north and a bit east of Mu Orionis. When the term 'open cluster' is mentioned, the mind's eye image is of a group of stars in the eyepiece. However, not all are bright enough to show such a view and NGC 2141 falls into this category. Despite being listed at mag. +9.4, smaller instruments are unable to resolve any of the cluster's stars; you will see a mistiness behind a number of brighter foreground stars. You need a 300mm aperture to show the 20 individually resolved stars. ☐ **SEEN IT**

5 NGC 2194

Located 3.5˚ northwest of NGC 2141 and half a degree northwest of the mag. +5.4 star 73 Orionis, is the open cluster NGC 2194. This has a similar size to our previous target, but is slightly brighter with a listed integrated magnitude of +8.5. A 150mm scope shows a misty glow sprinkled with six or so individual stars. A 250mm scope doubles the number of individual stars seen and reveals a granular texture to the mistiness, while a 300mm scope allows you to drill down into the cluster's core where several tens of stars can be individually resolved. ☐ **SEEN IT**

6 NGC 2169

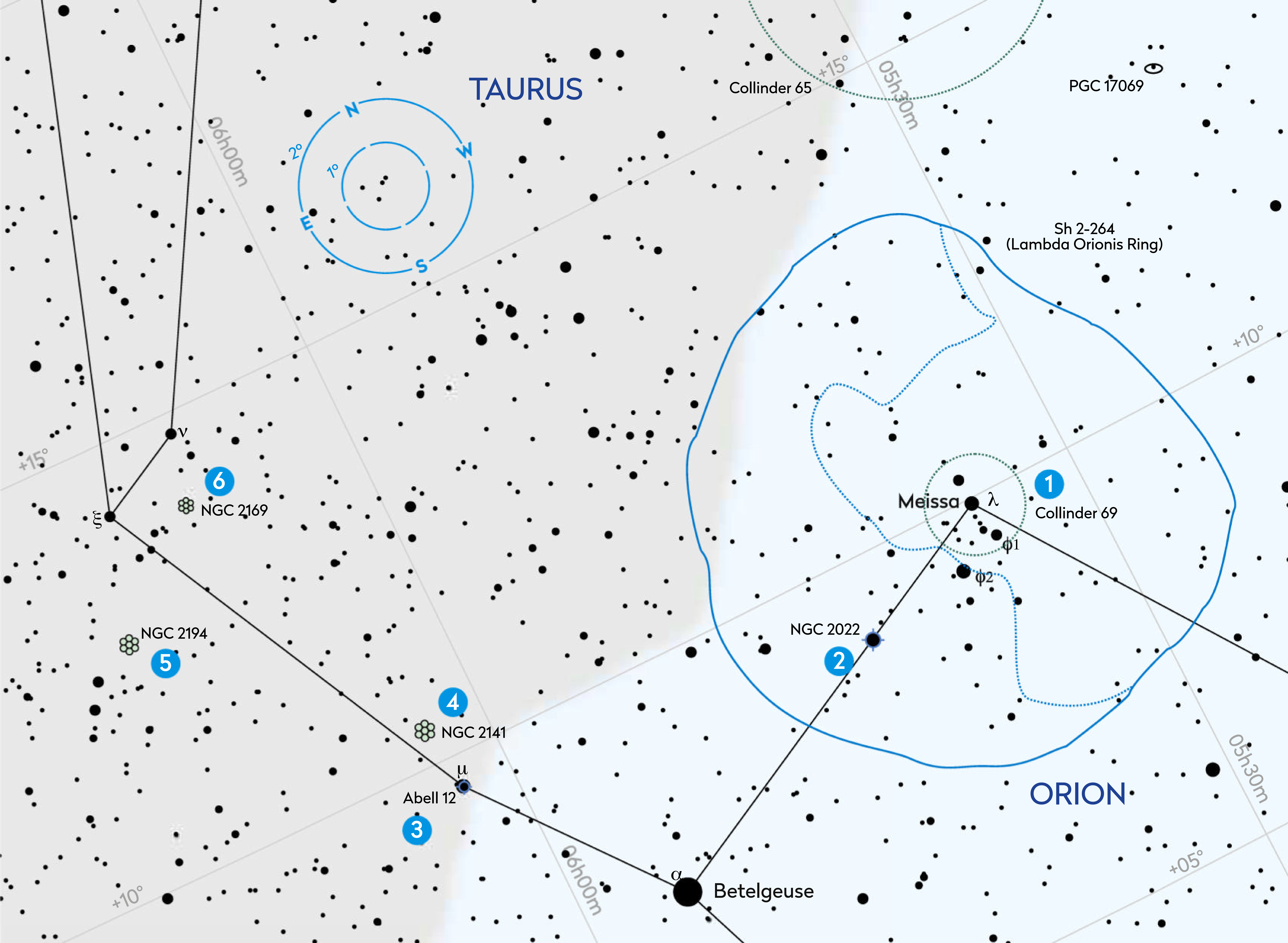
The stars in our final object appear to form the number '37' or perhaps less attractively, a shopping trolley! Listed at mag. +5.9, a small scope will show NGC 2169, containing 16 stars in a 5 arcsecond area. The count increases to around 20 cluster members through a 300mm telescope. Look for the contrast in colour between most of the stars and the two which mark the join between the vertical and horizontal components of the '7'. This pair is double star Struve 844 and looks orange compared to the white and blue-white colour of the others. The brightest star in the top of the '3' is double star Struve 848, with mag. +6.9 and +7.8 components separated by 2.6 arcseconds. ☐ **SEEN IT**

This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

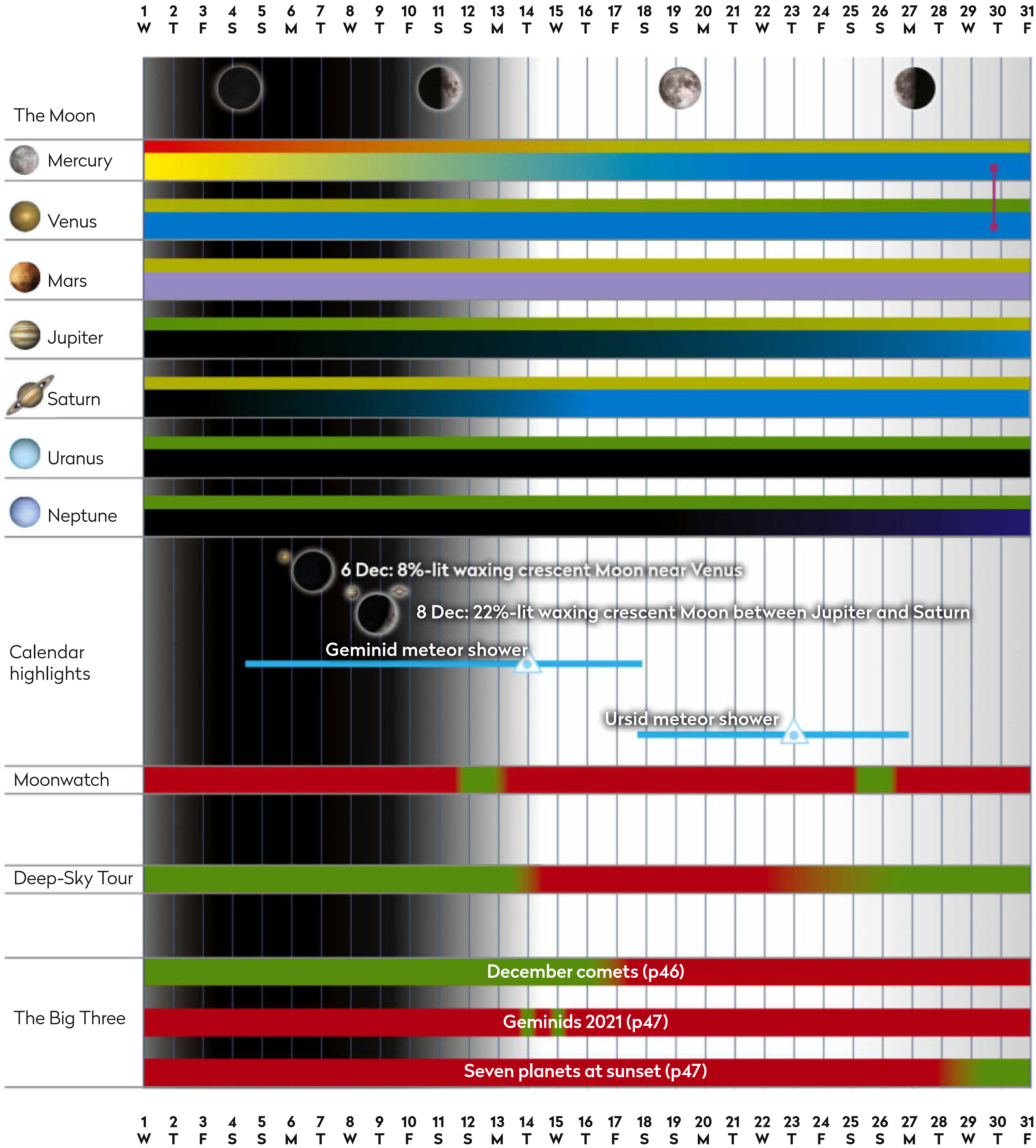
More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.



TAURUS
ORION
PGC 17069
Sh 2-264
(Lambda Orionis Ring)
Collinder 65
Collinder 69
Meissa
λ
φ1
φ2
NGC 2022
Betelgeuse
α
μ
Abell 12
NGC 2141
NGC 2169
NGC 2194
ν
ξ
1
2
3
4
5
6
N
S
E
W
1°
2°
05h30m
06h00m
+05°
+10°
+15°

AT A GLANCE How the Sky Guide events will appear in December



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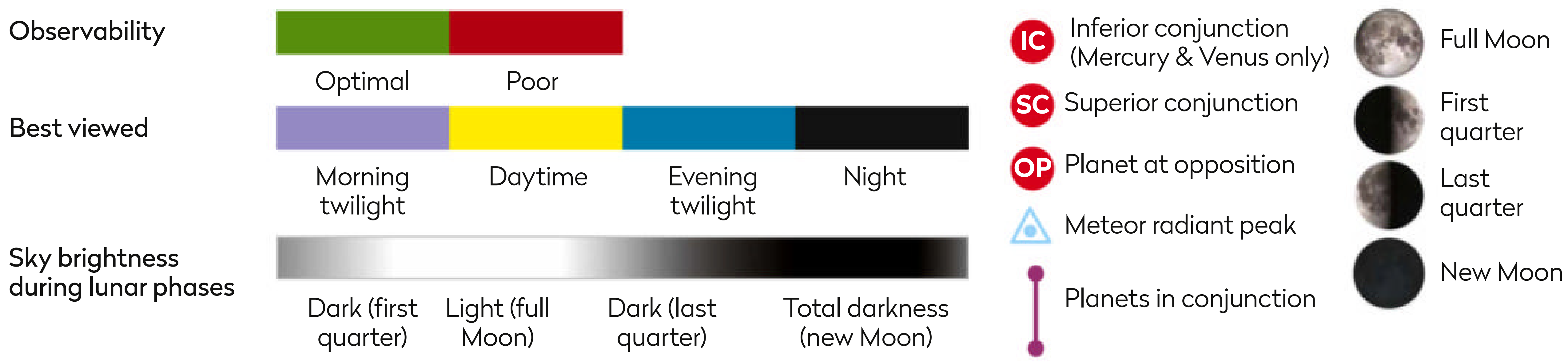
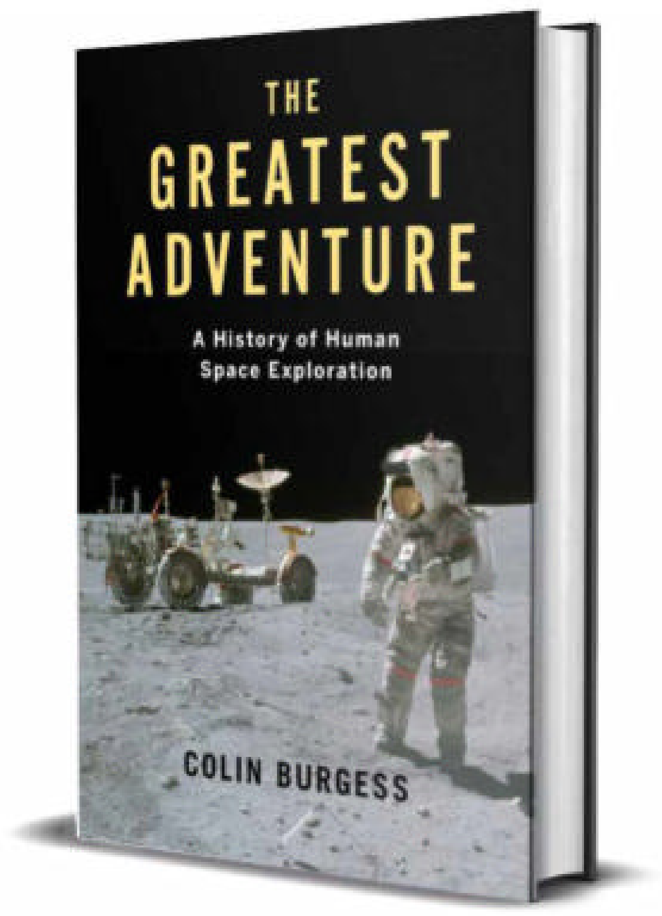


CHART BY PETE LAWRENCE

ASTRONOMER'S GIFT GUIDE



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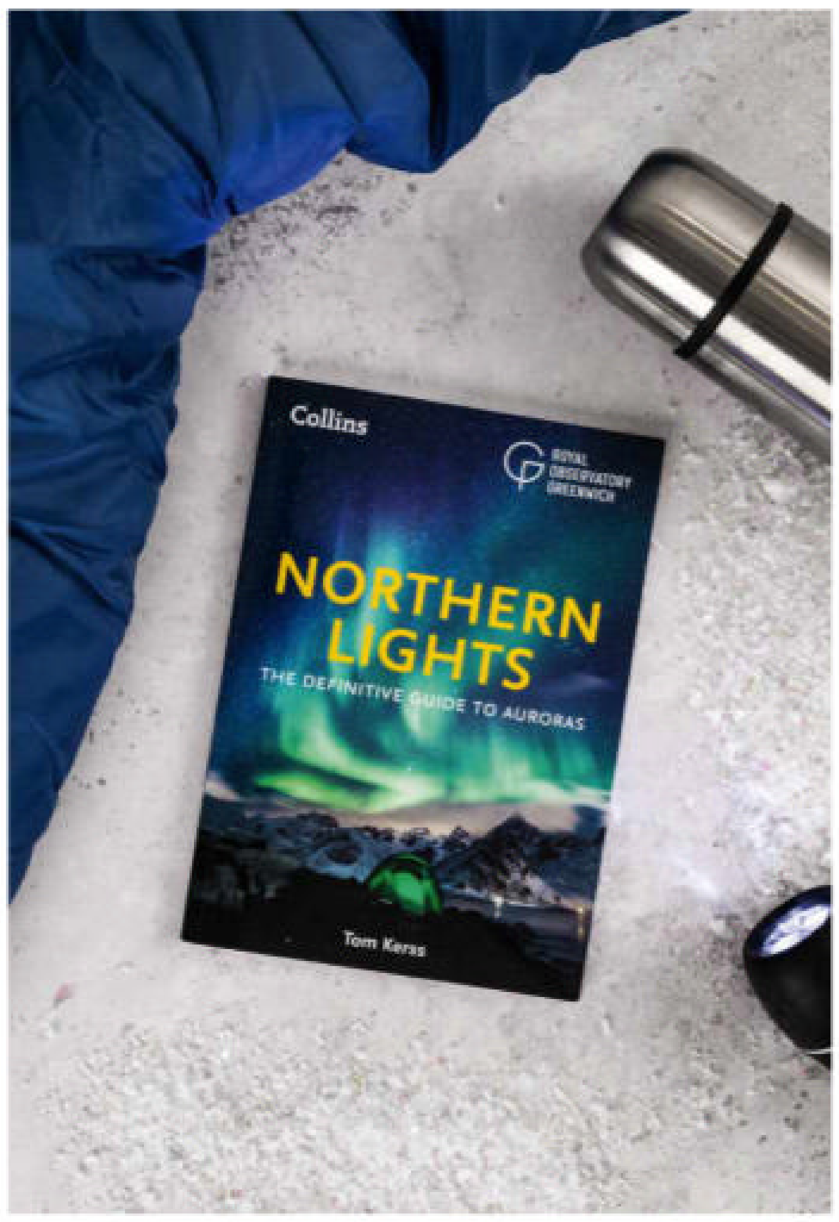
Martha Jackson



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A modern-day representation of Canes Venatici, the Hunting Dogs, from the popular planetarium program Stellarium. The constellation is best seen from after midnight to before dawn this month

Who let the dogs out?

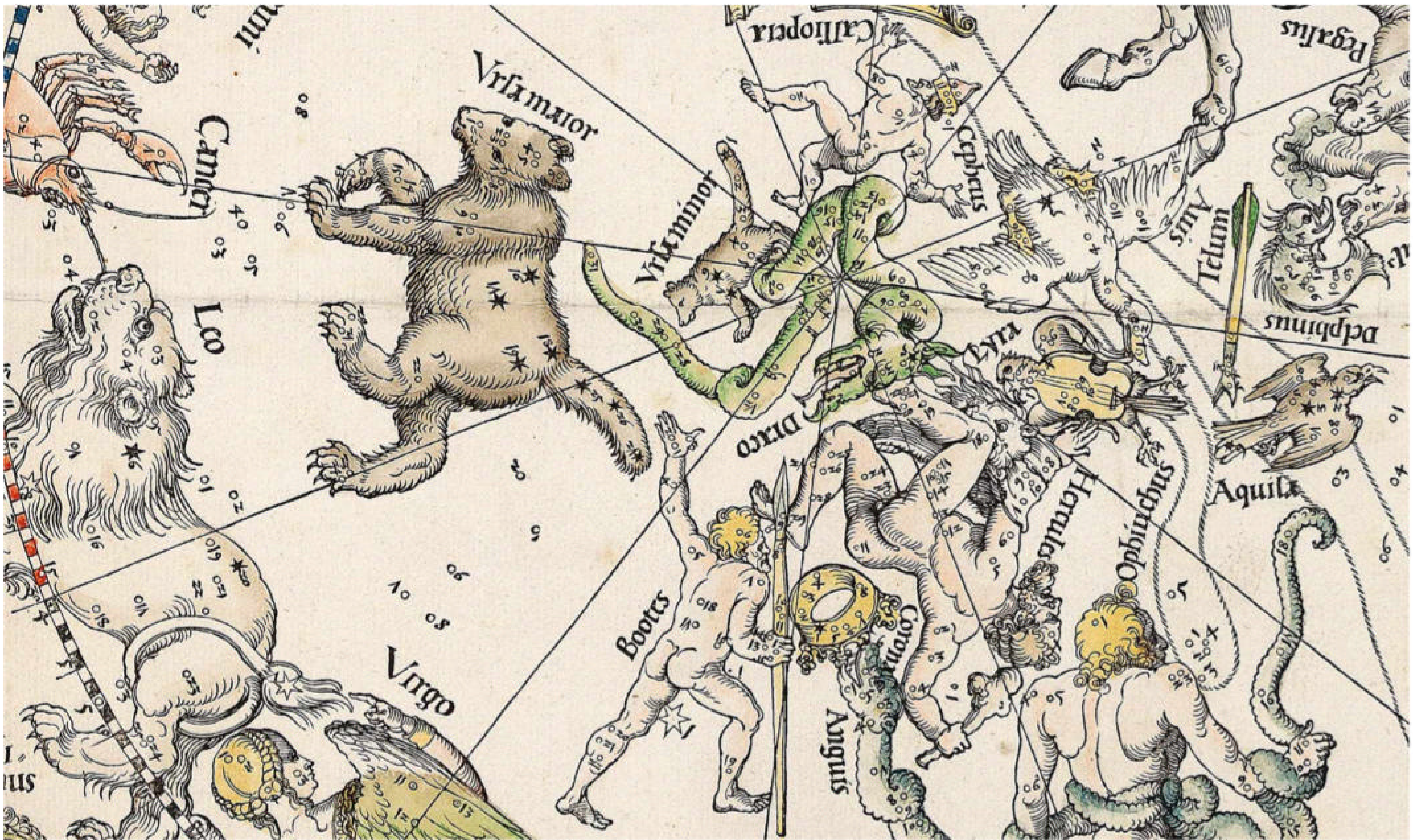
The origin of Canes Venatici, the Hunting Dogs, can be traced to the 17th century, but who deserves credit? **Ian Ridpath** picks up the scent

Two dogs snap at the heels of the Ursa Major, the Great Bear, in a nightly chase around the north celestial pole. These canines are the hunting hounds of Boötes, the Herdsman, who holds them on a leash in his outstretched hand. In Greek tradition, Boötes was visualised in several ways, usually herding or driving animals. One story says that the name Boötes comes from the Greek for ox driver, since the stars of the Plough were visualised as an ox cart. An alternative explanation is that the name comes from a Greek word meaning 'noisy', and we can perhaps imagine the sounds of the herdsman shouting to his animals in the night.

The two dogs of Boötes are represented by the constellation of Canes Venatici, but this isn't one of the 48 figures that the ancient Greek astronomer Ptolemy listed in his great source book, the *Almagest*, written around 150 AD.

Unlike the modern constellations, which fit neatly together, the Greek constellations didn't fill the entire sky. Between Boötes and Ursa Major was a large gap. Within it were two stars, which Ptolemy had classed among the 'unformed' stars outside Ursa Major, not part of any constellation and so free to use in a new figure. You can see this gap, and the two stars, on old charts of the Ptolemaic constellations such as the one by Albrecht Dürer (see below).

The brighter member of this pair of stars is known as Cor Caroli (Alpha (α) Canum Venaticorum) or 'Charles's Heart', a name given to it by British astronomers in the 17th century, before Canes Venatici was formed. How this name came about is a story in itself (see page 64). ▸



▼ **Two lone stars just below the tail of Ursa Major, the Great Bear, in this 1515 star chart by Albrecht Dürer would later become part of the constellation of Canes Venatici, the Hunting dogs – as defined by Johannes Hevelius**

STELLARIUM, IMAGE COURTESY OF DANIEL CROUCH RARE BOOKS/CROUCHRAREBOOKS.COM

◂ **Johannes Hevelius (top) clashed with the Royal Society's Robert Hooke (bottom) about the use of instruments with telescopic sights**

▸ The prime mover behind the introduction of the constellation of Canes Venatici, the Hunting Dogs, to the sky was Johannes Hevelius (1611–87), a wealthy brewer from Danzig, (now Gdańsk, Poland), who was one of the greatest observers of his age. He used his wealth to create a rooftop observatory equipped with top-quality instruments of his own construction. His interests were wide-ranging and his output prolific: he observed sunspots, comets and the variable star Mira (Omicron (ο) Ceti) – which he named, plus a transit of Mercury, the moons of Jupiter and the rings of Saturn. He also produced the first atlas of the Moon, *Selenographia*. Like his hero Tycho Brahe (1546–1601), Hevelius published his results on his own printing press.

The underlying aim for much of his life, though, was to improve on Tycho's catalogue of a thousand stars. Had he wished, Hevelius could have produced the first-ever star catalogue made with a telescope, ahead of John Flamsteed at Greenwich, but he was concerned that lenses might introduce positional distortions. Instead, he relied on simple naked-eye sighting instruments, such as sextants and quadrants similar to those used by Brahe in pre-telescopic days. Hevelius claimed that their quality and his sharp eyesight were a match for smaller instruments with telescopic sights.

This brought Hevelius into conflict with the Royal Society, which had elected him as a member in 1664. Robert Hooke, in particular, doubted that his results would be a match for telescopic measurements, but Hevelius disagreed. To resolve the issue, Edmond Halley went to visit Hevelius and observed alongside him using a quadrant with telescopic sights.

Hevelius was a brewer and Halley liked a glass of ale, so the two got on famously and, upon his return, Halley was happy to endorse the accuracy of Hevelius's results. Subsequent analysis has shown

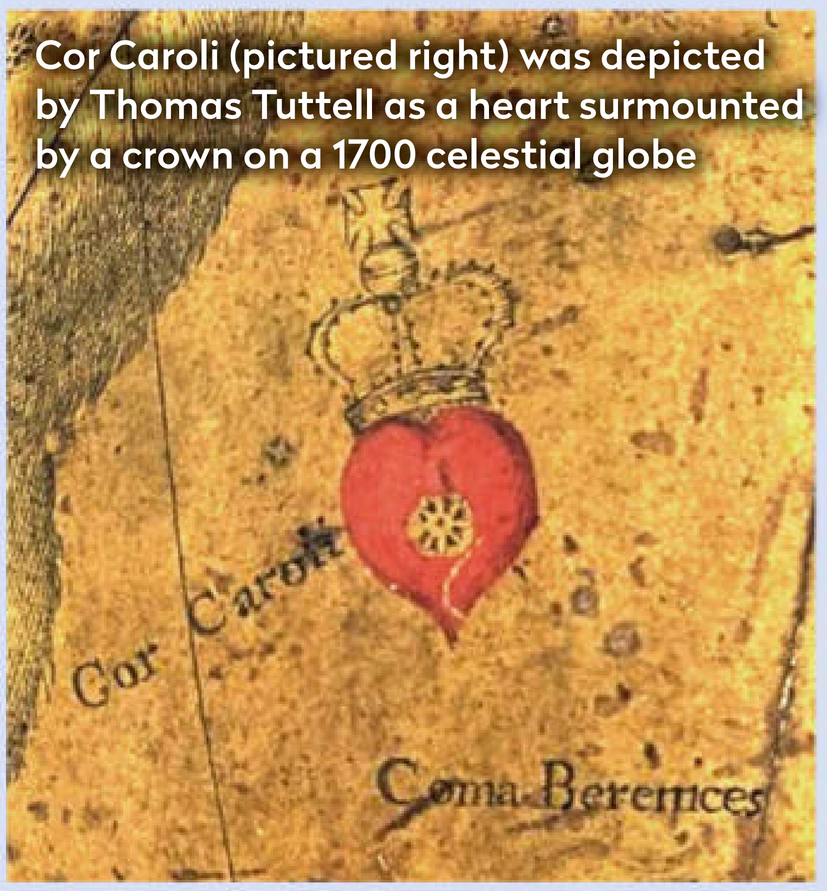
Cor Caroli – the heart of King Charles

The brightest star in Canes Venatici has a rich history of its own

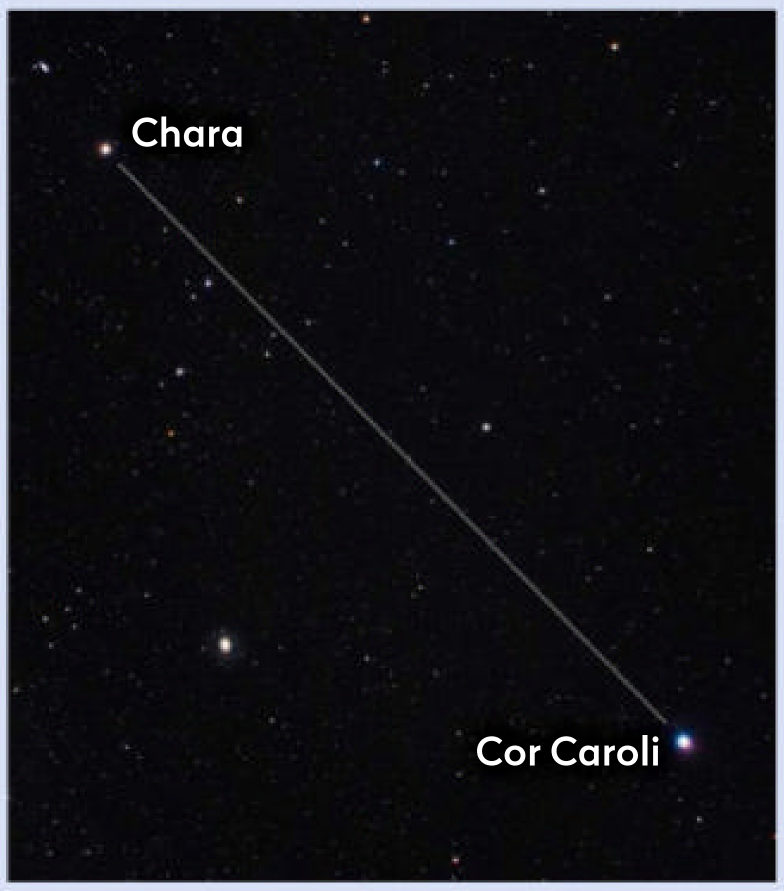
Before Boötes acquired his canine companions there was another mini-constellation in this area known as Cor Caroli, Charles's Heart. The poet Edward Sherburne (1616–1702) wrote in his translation of *The Sphere of Marcus Manilius* that the name was "...in Memory of the most Glorious Prince and Martyr, Charles the First", and that the King's physician, Sir Charles Scarborough, had come up with the idea.

According to historian Deborah Jean Warner, the name first appeared in print in 1673 on the northern half of a pair of celestial hemispheres by the cartographer Francis Lamb. He labelled the star Cor Caroli Regis Martyris ('Heart of Charles the Martyred King') – Charles I had declared himself "the martyr of the people" at his 1649 execution. On his chart, Lamb drew a heart and crown around the star, making it a mini-constellation. Sherburne followed suit, as did instrument maker Thomas Tuttell.

In his Bedford Catalogue of 1844 WH Smyth stated it was named Cor Caroli by Edmond Halley, at the suggestion of Scarborough after he noticed a star,



Cor Caroli (pictured right) was depicted by Thomas Tuttell as a heart surmounted by a crown on a 1700 celestial globe



which Johannes Helvelius had made part of Chara's collar, was shining brighter than usual on the night before Charles II returned to London. Smyth gave no source for this assertion, which, as well as being astronomically unlikely, compounds three errors: 1) the star wasn't named by Halley; 2) it was named before Hevelius had created Canes Venatici; and 3) the name doesn't refer to Charles II.

However, Smyth can claim he was misled about Halley and Charles II because he was repeating what Johann Bode had said (wrongly) in an 1801 star catalogue.

Could such a brightening have really happened? Cor Caroli is slightly variable, but its fluctuations are too small for the naked eye. The possibility that it should have brightened on the night of Charles II's return is undoubtedly apocryphal.

▲ **After naming the constellation of Canes Venatici, the Hunting Dogs, Hevelius depicted them as greyhounds in his *Firmamentum Sobiescianum* star atlas, published posthumously in 1690**

that his star positions were indeed more accurate than Brahe's.

The *Catalogus Stellarum Fixarum* ('Catalogue of Fixed Stars') by Hevelius contained over 1,500 stars, 50 per cent more than either Ptolemy or Brahe had recorded, giving him plenty of raw material from which to fashion new constellations in the gaps between the ancient figures. The catalogue was in the process of being printed in 1687 when Hevelius died. It was seen through to publication by his wife Elisabeth, eventually appearing in 1690 along with a magnificent atlas, *Firmamentum Sobiescianum*, named in honour of the Polish king, John III Sobieski.

Long-lasting appeal

Along with the Ptolemaic figures, the catalogue and atlas of Hevelius contained 10 constellations of his own devising, seven of which we still use today: Canes Venatici, the Hunting Dogs; Lacerta, the Lizard; Leo Minor, the Smaller Lion; Lynx; Scutum, the Shield; Sextans, the Sextant; and Vulpecula, the Little Fox.

The depiction of Canes Venatici by Hevelius can be seen in his 1690 atlas (pictured above). As on all of his charts, the constellation is drawn as it would appear on a globe, so it appears back-to-front compared to the way we see it in the sky. The dogs are meant to be greyhounds, which hunt as a pair, although they might not look like it the way they're drawn on some charts. Hevelius named the northern dog Asterion and the southern one Chara (he deemed them to be male and female respectively).

Chara, leading the chase, is clearly the top dog as she contains the two unformed stars listed by Ptolemy, of third and fourth magnitude, now known as Alpha (α) Canum Venaticorum and Beta (β) Canum Venaticorum. These designations were allocated by the English astronomer Francis Baily in his *Catalogue of Stars of the British Association for the Advancement of Science* of 1845, since Hevelius didn't use Greek letters on his charts. Alpha (α) Canum Venaticorum is Cor Caroli. By contrast, Chara's kennel-mate Asterion is marked by only a scattering of faint stars.

Although Hevelius is rightly credited with the invention of the constellation of Canes Venatici, he was not the first to show dogs in this area. That honour goes to the German astronomer Peter Apian ►

Along with the Ptolemaic figures, the catalogue and atlas by Hevelius contained 10 constellations of his own devising, seven of which we still use today: Canes Venatici, Lacerta, Leo Minor, Lynx, Scutum, Sextans and Vulpecula

◂ Boötes is shown with two dogs in this 1533 star chart by Peter Apian, published over 150 years before Helevius introduced the Canes Venatici constellation

▴ In 1536 Apian issued a new star chart in which Boötes had acquired a third hunting dog at his heels

▸ (Petrus Apianus in Latin) who published a star chart showing Boötes with two dogs in 1533 (pictured above, top), 150 years before Hevelius. Three years later, on another of Apian's charts, the number of dogs had grown to three (pictured above).

Was Boötes a dog owner?

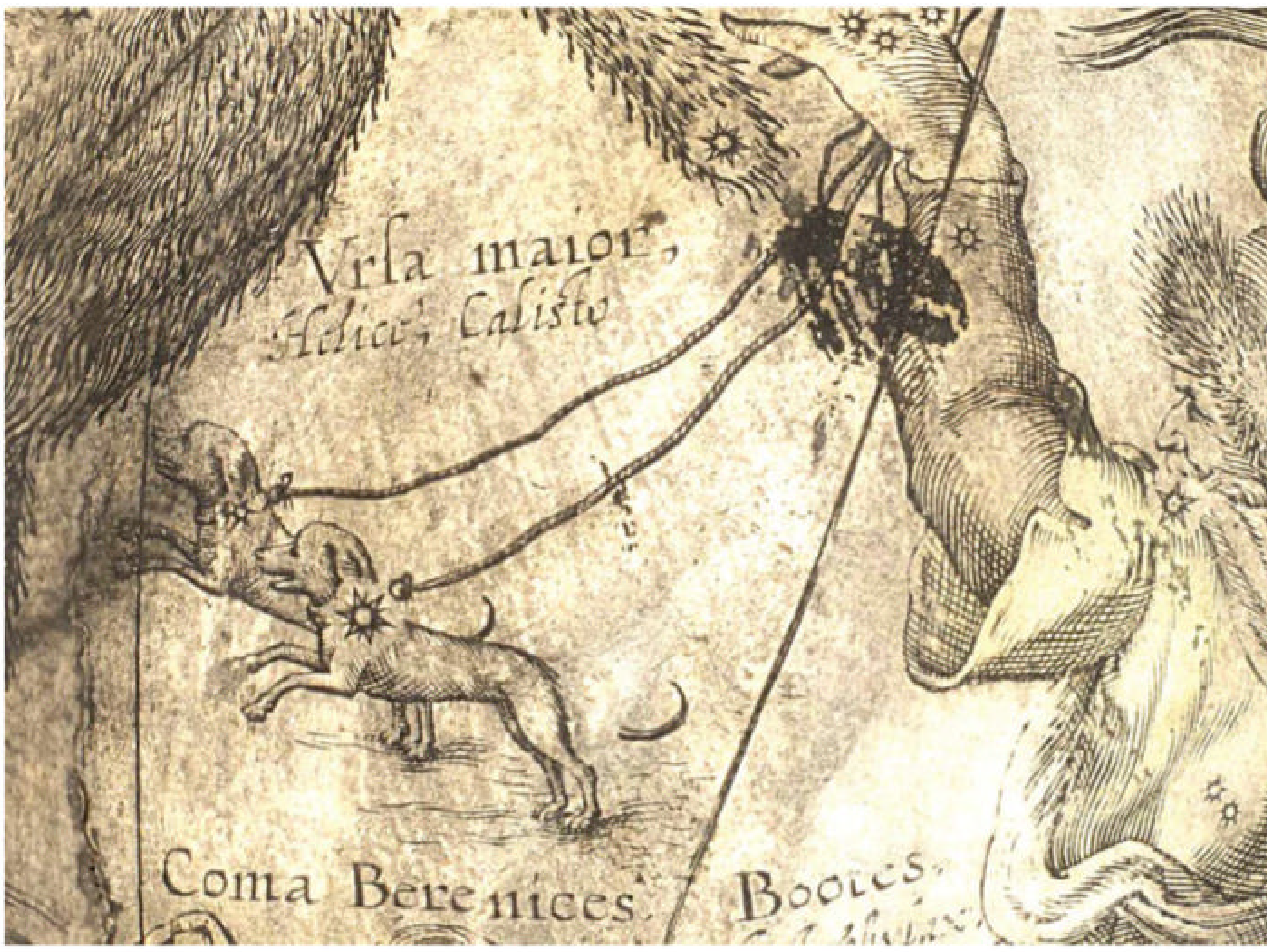
Where did Apian get the idea that Boötes might be a dog owner? Certainly not from Greek myth, as there's no mention of canine companions there. The star name expert Paul Kunitzsch has traced the origin of the idea to a bizarre mistranslation in the 12th century. Gerard of Cremona, who was retranslating an Arabic-language version of the *Almagest* into Latin, apparently mistook the Arabic word *al-kullāb*, referring to the shepherd's crook carried by Boötes, for *al-kilāb*, which means dogs. He ended up with a garbled phrase implying that Boötes carried a staff with dogs. Apian evidently read this incorrect translation and added the dogs to his Boötes image.

Apian's dogs can't really be considered forerunners of Canes Venatici since, unlike the greyhounds of Hevelius, they were still following Boötes and not the Great Bear. What's more they didn't incorporate any of Ptolemy's stars. A more plausible prototype appeared on a celestial globe of 1602 made by the eminent Dutch cartographer Willem Janszoon Blaeu (1571–1638). On this we see Boötes holding two dogs that are following the Great Bear (pictured below), as in the constellation of Hevelius. The lead dog is marked by Beta Canum Venaticorum and the follower by Cor Caroli. This was the first attempt to incorporate the two brightest stars in this area into a pair of dogs, although Hevelius achieved it differently by allocating both stars to Chara, the southern dog.

Did Hevelius take his idea from Blaeu's globe? He didn't say, but the similarity between Blaeu's dogs and the later constellation of Hevelius is striking. Perhaps the history of the constellations should be revised to give Blaeu a share of the credit for the formation of Canes Venatici.

Next time you're out, see if you can spot these two leaping greyhounds, and the heart of King Charles, in the space between Boötes and the Great Bear.

Ian Ridpath is a veteran populariser of astronomy and the editor of the *Oxford Dictionary of Astronomy*. Find out more about him at **www.ianridpath.com**



▴ A 1602 depiction of the Hunting Dogs from a globe by Willem Janszoon Blaeu shows each dog marked by the unformed stars listed by Ptolemy

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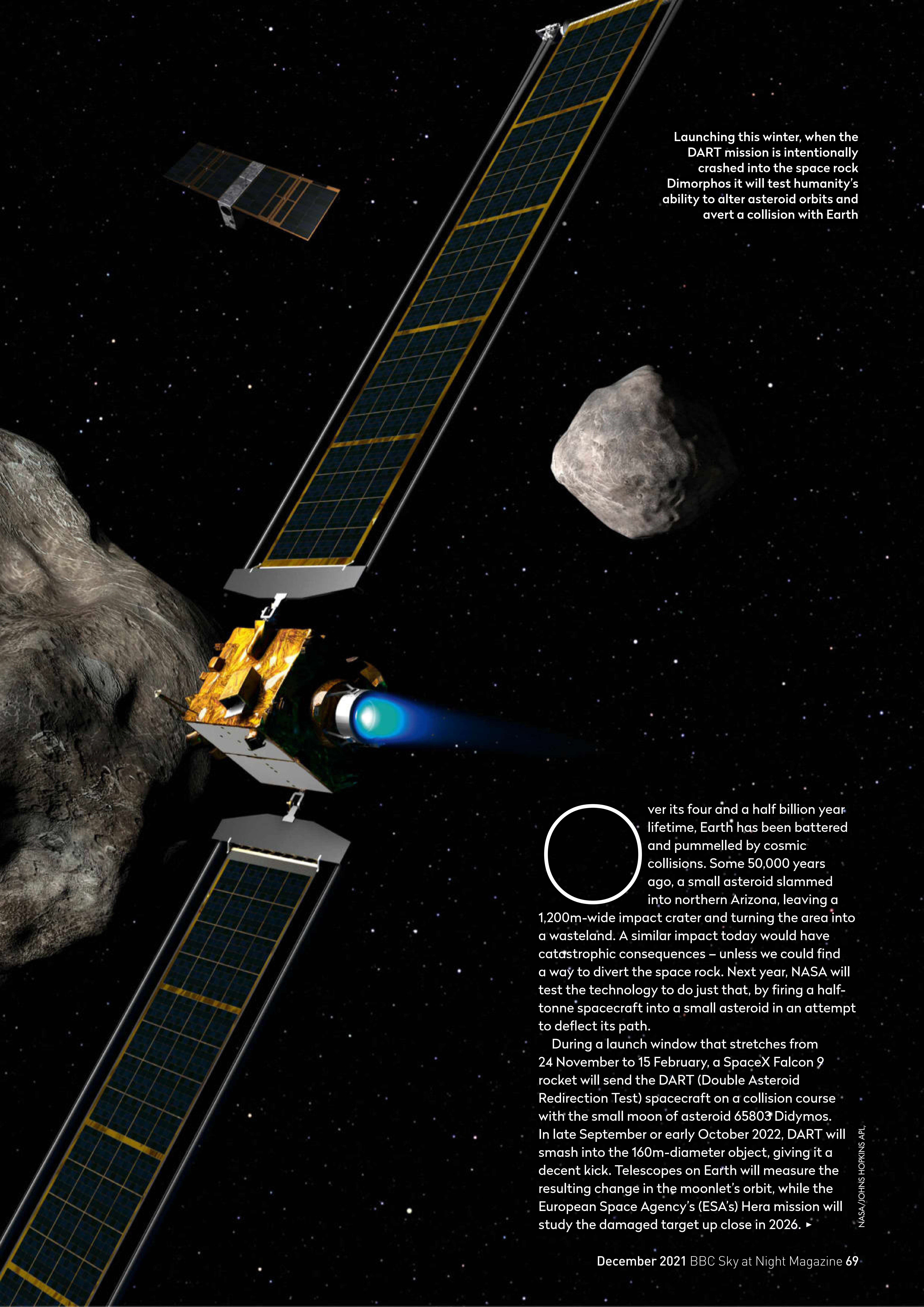
DART A mission with impact

Govert Schilling takes a look at the NASA mission that will attempt to deflect an asteroid, part of a collaboration with ESA that could save Earth from a catastrophic impact

ILLUSTRATION



Launching this winter, when the DART mission is intentionally crashed into the space rock Dimorphos it will test humanity's ability to alter asteroid orbits and avert a collision with Earth

NASA/JOHNS HOPKINS APL,

Over its four and a half billion year lifetime, Earth has been battered and pummelled by cosmic collisions. Some 50,000 years ago, a small asteroid slammed into northern Arizona, leaving a 1,200m-wide impact crater and turning the area into a wasteland. A similar impact today would have catastrophic consequences – unless we could find a way to divert the space rock. Next year, NASA will test the technology to do just that, by firing a half-tonne spacecraft into a small asteroid in an attempt to deflect its path.

During a launch window that stretches from 24 November to 15 February, a SpaceX Falcon 9 rocket will send the DART (Double Asteroid Redirection Test) spacecraft on a collision course with the small moon of asteroid 65803 Didymos. In late September or early October 2022, DART will smash into the 160m-diameter object, giving it a decent kick. Telescopes on Earth will measure the resulting change in the moonlet's orbit, while the European Space Agency's (ESA's) Hera mission will study the damaged target up close in 2026. ▸

With a diameter of 1,200km, Meteor Crater in Arizona, USA was caused by the impact of a meteor 50m across some 50,000 years ago. A bus parked nearby is circled for scale

▸ Ever since the discovery of 433 Eros in 1898 – the first asteroid known to cross the orbit of Mars – astronomers have realised that Earth is at risk from cosmic impacts. Today, they know of over 2,200 'potentially hazardous asteroids' (PHAs): objects larger than 140m in diameter that can approach our planet to within 7.5 million kilometres. Smaller ones are even more numerous. Tiny space rocks, just 10m or 20m wide, are regularly seen passing within the Moon's orbit, or exploding in the atmosphere, like the Chelyabinsk impactor in February 2013.

While the Chelyabinsk blast did not claim any lives, a 100m-wide asteroid could destroy a large city. Objects that size collide with Earth once every 5,000 years or so, on average. Increasing the diameter to 400m brings the impact frequency down to once every 100,000 years, but the damage is proportionally larger and could wipe out an area the size of France.

"We need to find those objects before they find us," says Kelly Fast, director of NASA's Planetary Defense Coordination Office.

Making an impact

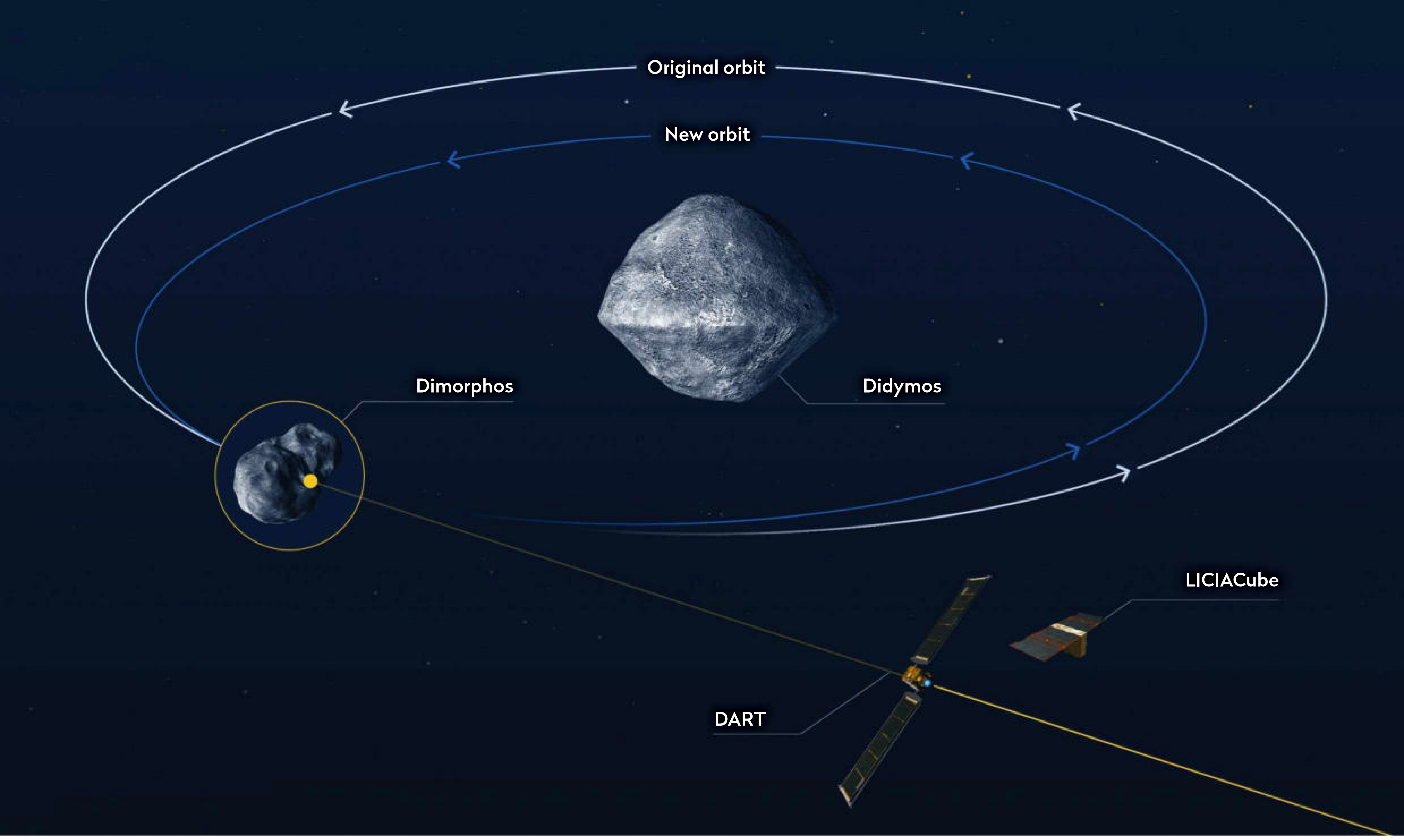
Searching for and finding an asteroid is one thing, but doing something about it is another. And while astronomers are constantly discovering new NEOs (near-Earth objects), there is no single existing programme for defusing an approaching cosmic missile. Scientists don't even know what the best strategy would be, although the 'kinetic impactor' technique – basically, kicking the oncoming rock out of the way – appears to be a relatively simple, effective and cheap solution. Except that no one has ever tried it.

With DART, that's going to change. Next year, the 360kg spacecraft, about the size of a golf cart, will deliberately crash itself into a small asteroid at a velocity of 6.6km/s. DART is a very basic spacecraft, developed and built by the Johns Hopkins Applied Physics Laboratory, and fitted out with little more than an ion engine, a few small thrusters, five Sun sensors and a star tracker, simple radio antennas for communicating with Earth and a camera. Power will be provided by two roll-out solar arrays, each measuring 8.6m x 2.3m. And all of this will be intentionally destroyed less than a year from now, when DART slams into its target.

▲ In 2013, an 8m-diameter hole in the ice of Russia's Lake Chebarkul was thought to have been caused by a fragment of the Chelyabinsk meteor

That target is known as Dimorphos and it measures approximately 160m across. It's in orbit around asteroid Didymos (Greek for 'twins'), which is almost five times larger, at 780m in diameter. Didymos is a typical near-Earth asteroid, discovered in 1996 by the Spacewatch project at Kitt Peak National Observatory in Tucson, Arizona. It rotates every 2.26 hours, and its elliptical orbit of the Sun takes it from the main asteroid belt

IFRPILOT/ISTOCK/GETTY IMAGES, NEWSCOM/ALAMY STOCK PHOTO, NASA/JOHNS HOPKINS APL, NASA/JPL-CALTECH



to just outside Earth's orbit and back every 2.11 years.

Astronomers discovered Dimorphos in 2003. This small moon of Didymos orbits the main asteroid every 11.9 hours at a distance of just 1.2km, moving at a leisurely pace of some 0.2m/s – comparable to the walking speed of a tortoise. The destructive impact of the DART spacecraft will change this velocity by less than a millimetre per second (after all, hitting a 5 billion kilogram asteroid with a 500kg spacecraft is like throwing a peppercorn at the tortoise), but this should change the moon's orbital period by about 10 minutes – enough to be measurable from Earth.

▲ The intention of the DART impact is to alter the orbit that the moon Dimorphos takes around asteroid Didymos. The event will be witnessed by the LICIACube satellite

Anticipating reactions

The truth is, however, that nobody really knows exactly what will happen.

"It all very much depends on the internal structure of the target," explains Fast. A solid body will respond differently from a relatively loose 'rubble ▸

Lucy and the Trojans

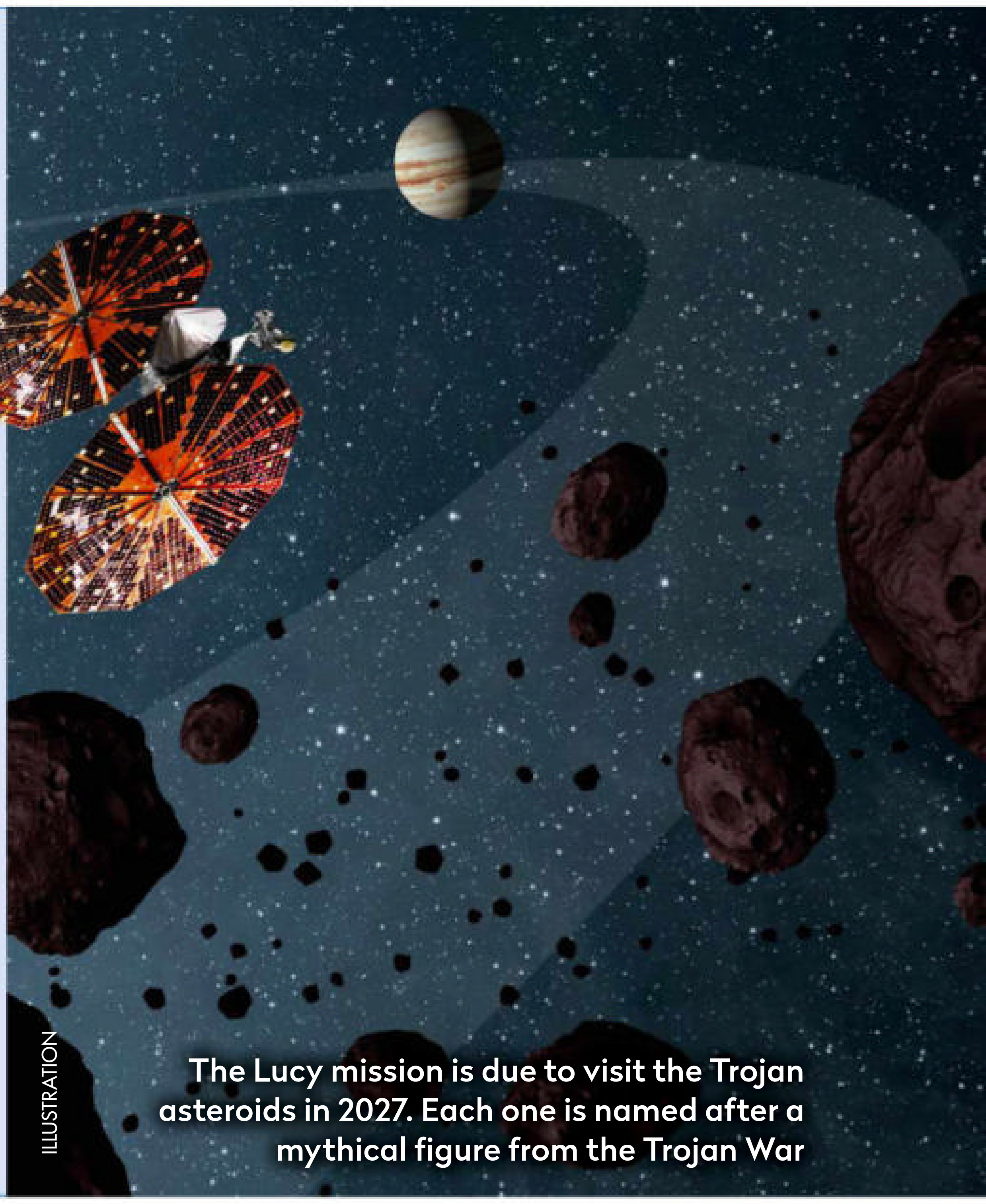
The mission will increase our knowledge of the asteroid swarms orbiting with Jupiter

By the time you're reading this story, NASA's Lucy mission should be on its way to study the Trojan asteroids, having launched in October 2021. Trojans are asteroids that share Jupiter's orbit around the Sun, either 60° ahead or 60° behind the giant planet. There's thought to be at least a million of them larger than 1km in diameter.

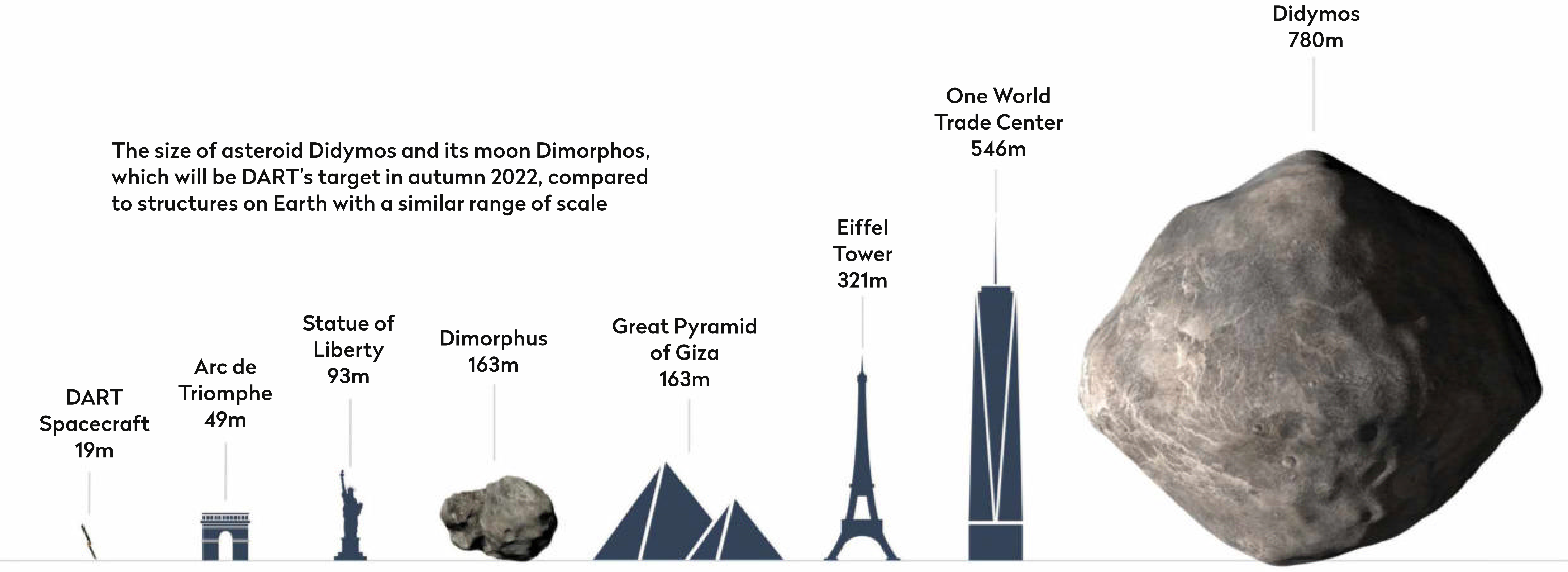
Launched on an Atlas V rocket, Lucy will perform gravity assist flybys with Earth in 2022 and 2023 to gain speed. In 2025, it will fly by the main belt asteroid 55246 Donaldjohanson, named after the paleoanthropologist who discovered the 'Lucy' hominin fossil after which the mission has been named. In 2027, Lucy will arrive in the 'leading' cloud of Trojans, studying four of them in detail.

Next, a third gravity assist with our home planet in 2031 will send the spacecraft to the trailing cloud, where it will orbit the second-largest Trojan, 617 Patroclus (140km in diameter), which is accompanied by a smaller companion body known as Menoetius.

Lucy's visual imager, near-infrared imaging and thermal infrared spectrometers will study the composition and surface characteristics of these dark, puzzling objects, shedding light on their origin and, thus, on the early evolution of our Solar System.



The Lucy mission is due to visit the Trojan asteroids in 2027. Each one is named after a mythical figure from the Trojan War



The size of asteroid Didymos and its moon Dimorphos, which will be DART's target in autumn 2022, compared to structures on Earth with a similar range of scale

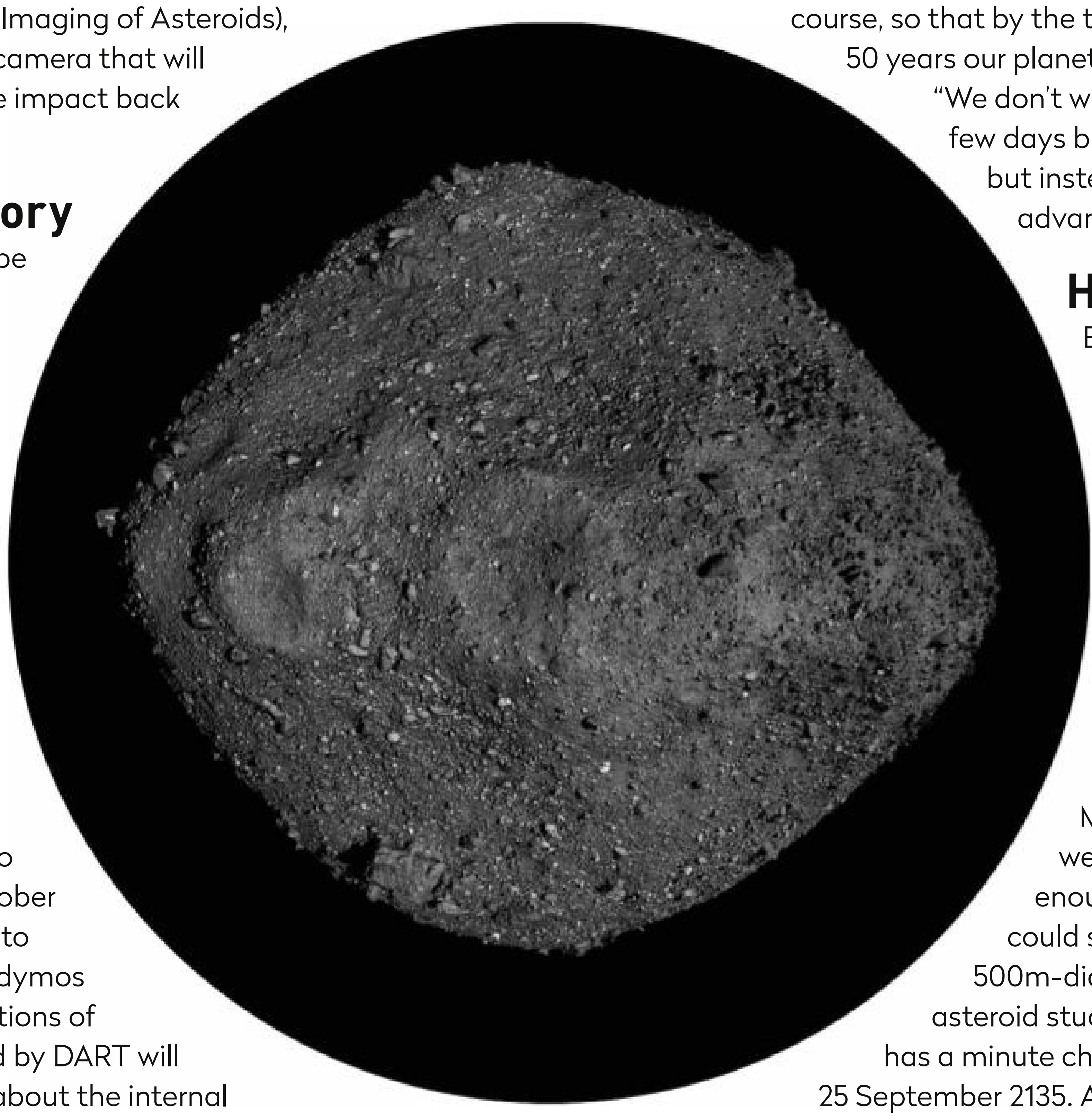
▸ pile'. Didymos may indeed resemble the rubble-pile asteroids Bennu and Ryugu, which have recently been studied in detail by NASA's OSIRIS-REx spacecraft and the Japanese Hayabusa 2, respectively, but Dimorphos probably has more internal strength. Only time will tell.

"It's the very first time we're doing this," says Patrick Michel of the Côte d'Azur Observatory in France, who is the principal investigator for ESA's Hera mission. "We simply have no idea about the result."

At the time of impact, Didymos will be some 11 million kilometres from Earth, so there won't be anything to see from the ground. To witness the collision from up close, NASA has selected the Italian firm Argotec in Turin to develop a small 'CubeSat' that will be released by DART just prior to its arrival. LICIACube, as the tiny satellite is called (Light Italian CubeSat for Imaging of Asteroids), is equipped with a camera that will relay pictures of the impact back to Earth.

An inside story

Of course, LICIACube will have about the same relative velocity to Didymos and Dimorphos as DART has, around 6.6km/s, so it will shoot past and be unable to study the aftermath of the collision in detail. That will be the task of the Hera mission, due to be launched in October 2024. Hera is going to rendezvous with Didymos in 2026; its observations of the crater produced by DART will tell scientists a lot about the internal structure and composition of the small asteroid moon, says Michel. To that end, the Hera mission will be fitted with optical and infrared cameras, a laser rangefinder and a hyperspectral imager. In addition, Hera may also carry two small CubeSats, as well as a tiny lander and impactor built by JAXA, the Japanese space agency.



▼ A larger asteroid like Bennu – as imaged here by the OSIRIS-REx spacecraft – may be a target for HAMMER, a larger 'kinetic impactor' which is under development

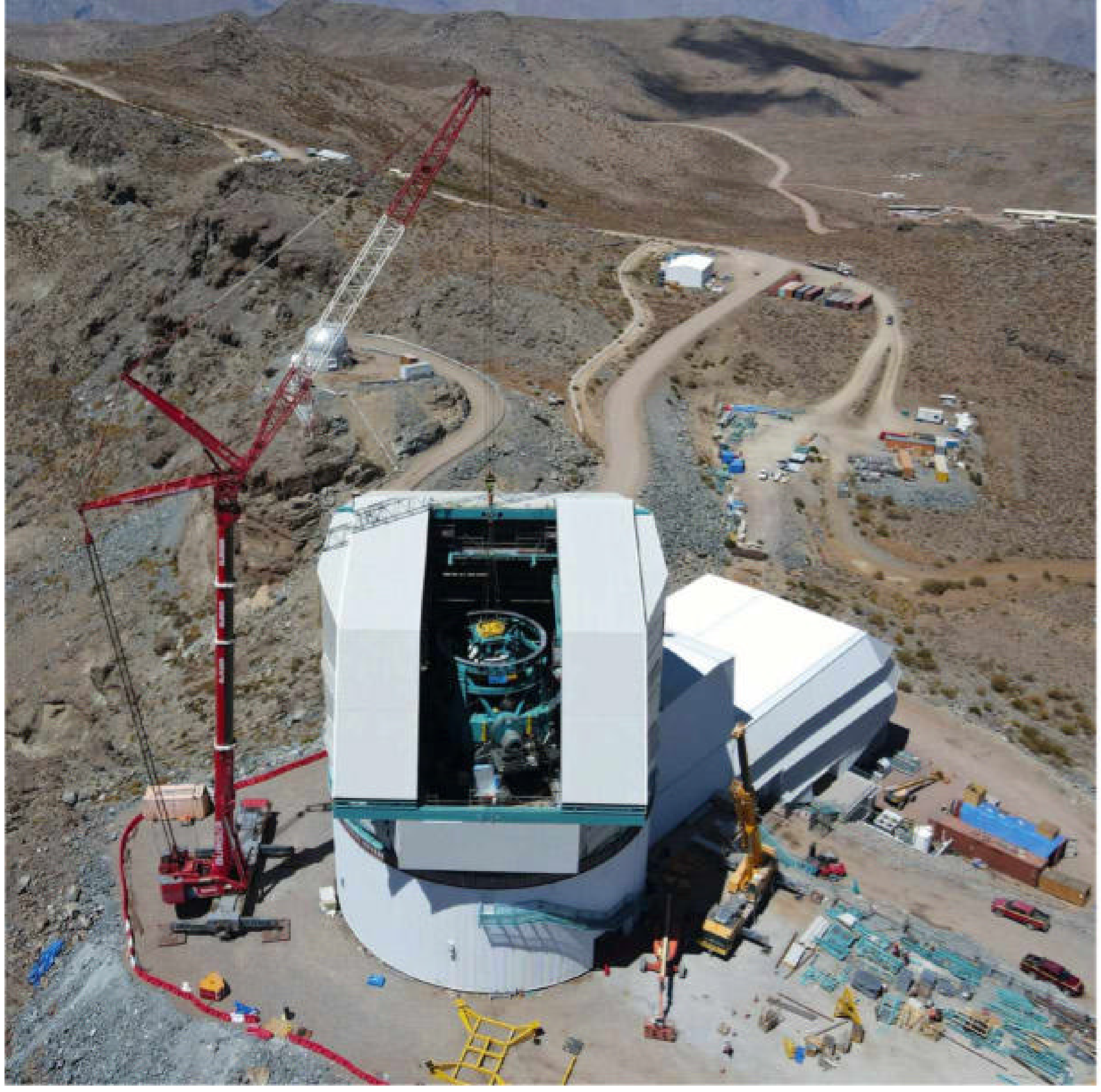
Of course, the real question is: will the experience and information gained by DART and Hera enable us to successfully ward off a potentially catastrophic asteroid impact in the future? That all depends on the particulars of such an event, says Amy Mainzer, a University of Arizona planetary researcher who is the project scientist for NEOWISE, NASA's space-based asteroid hunter. Suppose a near-Earth asteroid is detected tomorrow that is going to impact Earth in 2070. That gives us enough warning time: a tiny change of velocity now will be enough to change its course, so that by the time it crosses Earth's orbit in 50 years our planet will no longer be in its way.

"We don't want to discover these objects a few days before they are going to hit us, but instead many years or decades in advance," says Mainzer.

HAMMER time

Even then, a DART-like impact won't be enough to veer a much larger asteroid off course. That's why technicians at Lawrence Livermore National Laboratory have designed a much more powerful 'kinetic impactor', called HAMMER (Hypervelocity Asteroid Mitigation Mission for Emergency Response). Measuring 9m in length and weighing almost 9 tonnes, with enough warning time HAMMER could successfully deflect a 500m-diameter object like Bennu – the asteroid studied by OSIRIS-REx, which has a minute chance of impacting Earth on 25 September 2135. Alternatively, it could be

NASA/JOHNS HOPKINS APL, NASA/GODDARD/UNIVERSITY OF ARIZONA, RUBIN OBS/NSF/AURA, NASA/JPL-CALTECH/ASU, NASA/JPL-CALTECH/ARIZONA STATE UNIV./SPACE SYSTEMS LORAL/PETER RUBIN



used to kick a 30m-object out of the way if it was discovered only weeks before impact.

As far as planetary defence is concerned, discovery and mitigation are two sides of the same coin. The NASA office run by Fast is coordinating all US activities in this field, she explains, with a budget of about $150m per year. Moreover, the United Nations Committee On the Peaceful Uses of Outer Space (COPUOS) has installed two working groups to foster international collaboration: the Asteroid Warning Network and the Space Mission Planning Advisory Group. After all, threatening asteroids don't care too much about borders and nationalities, and a large impact would have global consequences.

▲ When the powerful Vera C Rubin Observatory, with its innovative three-mirror design, becomes fully operational, it is very likely to spot more potentially hazardous space rocks heading towards Earth

At present, astronomers don't know of any sizeable asteroid that will hit us in the next couple of centuries. But most of the estimated 15,000 or so potentially hazardous objects (the ones larger than 140m) are still undiscovered, and 50m-diameter space rocks are much more numerous still. When the Vera C Rubin Observatory in Chile comes online in late 2023, the number of new asteroid discoveries is going to explode, and it's likely it will spot one heading towards us before too long. By then, we will be grateful for the rehearsal opportunity that the DART mission offers.

The recent COVID-19 pandemic and the upcoming climate crisis have taught us that humankind is not particularly good at preparing for global catastrophes before they happen. In the case of cosmic impacts, the DART mission is at least a first step in finding out what can be done, so we are prepared to take charge and avert disaster when the need arises.

Govert Schilling is an astronomy journalist and broadcaster, and author of *Ripples in Spacetime.* The asteroid 10986 Govert is named after him

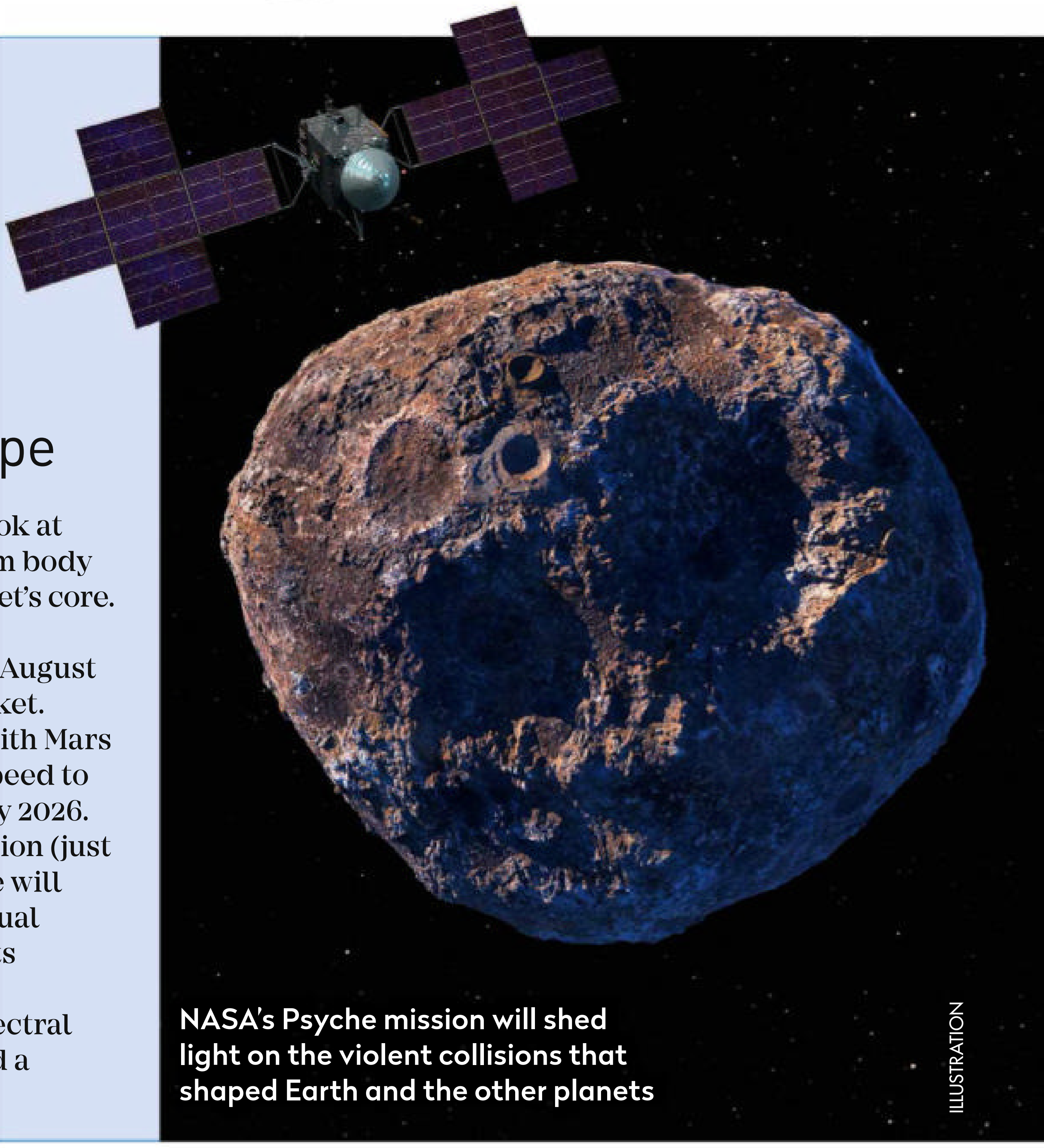
Psyche, the mission to the heavy metal asteroid

Its target is a resource-rich metallic body, one of the most massive of its type

Like Lucy, Psyche is a NASA Discovery-class mission to learn more about asteroids. Psyche will focus on only one: a 220km-diameter chunk of mostly iron and nickel, discovered in 1852, and bearing the same name.

16 Psyche is one of the 10 most massive known asteroids, due to its metal content – the surface is around 90 per cent metal. Most planetary researchers believe that Psyche is the exposed metallic core of a protoplanet that lost its silicate mantle in a collision with another asteroid, probably billions of years ago. If they're right, then the mission will offer a unique way to look at the interior of a Solar System body usually hidden inside a planet's core.

The launch of the Psyche spacecraft is scheduled for August 2022, on a Falcon Heavy rocket. In 2023, a close encounter with Mars will give the craft enough speed to reach its destination in early 2026. Using solar electric propulsion (just like DART and Lucy), Psyche will enter orbit around the unusual metallic asteroid, to study its properties and elemental composition with a multispectral imager, a magnetometer and a gamma-ray spectrometer.



NASA's Psyche mission will shed light on the violent collisions that shaped Earth and the other planets

ILLUSTRATION

The fundamentals of astronomy for beginners

EXPLAINER

ASTRONOMERS YOU SHOULD KNOW

Johannes Kepler

Jane Green looks at the life of the pioneering scientist and his laws of planetary motion

▲ **Johannes Kepler (1571-1630), described by astronomer Carl Sagan as the "first astrophysicist and the last scientific astrologer"**

A key figure in the scientific revolution of the 17th century, Johannes Kepler was an astronomer, mathematician, astrologer and staunch Lutheran. He was born on 27 December 1571 into a lower middle-class family in the town of Weil der Stadt (in today's southern Germany). In a pre-scientific, pre-Enlightenment era – driven by rival Protestant and Catholic Reformations – tensions, antagonisms, devil-fearing and witch-hunting were rife. Many people were persecuted for their beliefs.

Abandoned by a feckless soldier-of-fortune father, Heinrich, and a 'generally unpleasant' mother, Katharina, Kepler was brought up by grandparents. Small, sickly and sensitive, his hands and eyes disabled by smallpox, he took solace in God – the creator of all things – as he would throughout life.

Excelling in grammar, rhetoric, logic, arithmetic, geometry, music, astronomy, Greek and Hebrew in the Latin school system, a three-year theology scholarship at Tübingen University followed. Here he practised astrology – the 'foolish little daughter of the respectable, reasonable mother astronomy' – casting horoscopes for fellow students. He even played King Herod's wife in an outdoor theatre production.

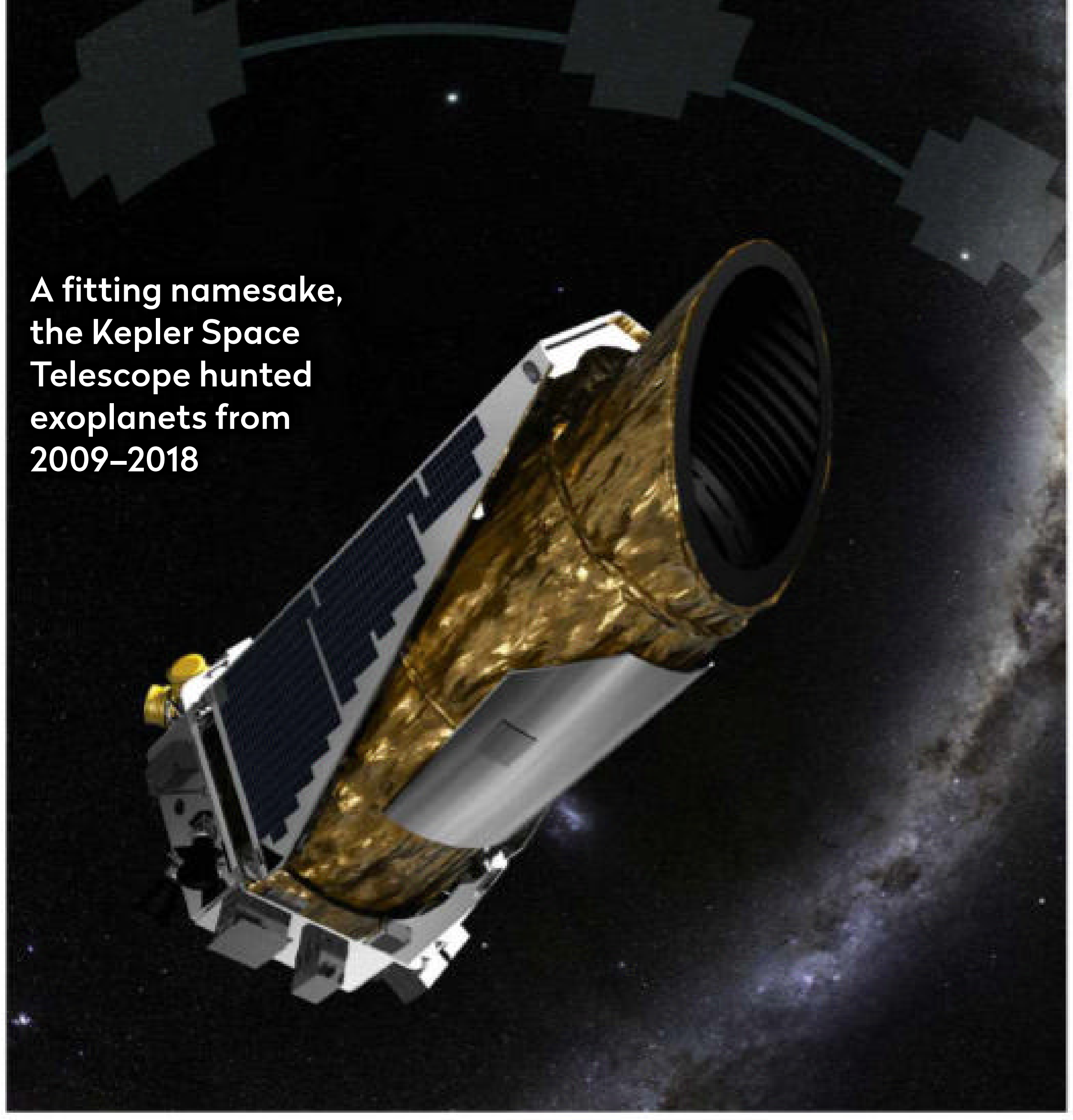
Aware of Ptolemy and Aristotle's Earth-centred Universe, it was the teacher and astronomer Michael Maestlin who introduced Kepler to the Sun-centred theory of Copernicus. Its unchanging, divinely-driven 'mechanical' movement sparked a lifelong obsession – a need to mathematically understand God's divine architecture, the harmony of the heavens.

Epiphany came when he was teaching at a boys' school in Graz, Austria. While demonstrating the periodic conjunction of Jupiter and Saturn he beheld the geometrical scaffolding on which all known planetary spheres were placed; overwhelmed, he wept. After lengthy calculation (and some fudging) God's geometrical plan, influenced by Copernicus and respecting the Bible, was revealed in his *Mysterium Cosmographicum*. Despite being sent a copy, Galileo offered scant approval. However, the great Danish observational astronomer Tycho Brahe was enthusiastic and they began a written correspondence, with Brahe hinting at possible future employment for Kepler.

Modelling planetary motion

Kepler proposed that the distance relationships between the six planets known at that time could be understood in terms of the five Platonic solids. In 1597 Kepler married the 'weak and annoying' Barbara Müller. Solitary, melancholic, somewhat chauvinistic and hydrophobic (he did not bathe for eight years!) Kepler focused on his principal work, *Harmonices Mundi* – a convoluted discussion of symmetry and cosmic harmony, where he geometrically embedded the five Platonic solids within the orbits of the six

IANDAGNALL COMPUTING/ALAMY STOCK PHOTO, HISTORIC ILLUSTRATIONS/ ALAMY STOCK PHOTO NASA AMES/JPL-CALTECH/T PYLE



A fitting namesake, the Kepler Space Telescope hunted exoplanets from 2009–2018

known planets and attributed the motions and eccentricities of them to musical intervals. Kepler was often wrong, but his *Harmonices Mundi* contained the third of his three laws of planetary motion – in which he states that the cube of the average distance of a planet from the Sun divided by the square of the time to complete one orbit is equal to a constant, a value applicable to all planets – and in this, as well as his first and second laws, he was proven spectacularly correct.

In 1600 Kepler joined Brahe at Benátky Castle near Prague where, along with Danish astronomer Christen Sørensen Longomontanus, he observed Mars. Frustrated by Brahe withholding data, Kepler returned to Graz. He would later return to Prague and, forgiven by Brahe, use his data to begin the *Rudolphine Tables* – a star catalogue and planetary almanac for Holy Roman Emperor Rudolph II.

After Brahe's death in October 1601, Kepler became Prague's Imperial Mathematician and he completed *Astronomia Nova* – the result of his 10-year investigation into the motion of Mars. It included his first and second laws of planetary motion; respectively planets orbit in ellipses with the Sun as one of the two foci (focus points) of each ellipse, and a line drawn from a planet to the Sun sweeps over equal areas in equal time.

▲ Above left: astronomers Tycho Brahe (right) and Johannes Kepler famously worked together in Prague, but not always harmoniously

Jane Green is an astronomy writer and author of the *Haynes Astronomy Manual*

Despite unrelenting heartache – Barbara's epilepsy, depression and death, the loss of their favourite son to smallpox, religious persecution, professional rivalry, remarriage and losing many offspring – he remained ahead of his time, immersing himself in his studies. Areas of interest included optics and optical anatomy; supernovae; Galileo's Jovian moons; telescope lenses and light transmission; telescope design (he invented a type of refractor); six-cornered snowflakes; and hexagonal packing of spheres and comets. He even defended his mother at a witch trial.

Kepler died in November 1630, aged 58. He left an astonishing legacy, not least of which proving that planets circle stars in elliptical, not circular, orbits, a theory on which space exploration depends. Isaac Newton's law of universal gravitation, published in 1687, crowned the cosmic structure Kepler had begun. Kepler was indeed the scientific giant upon whose shoulders other scientists metaphorically stood.

Five landmark works

A prolific writer, Johannes Kepler's published writings showcase major aspects of his scientific thinking

Mysterium Cosmographicum ('The Cosmographic Mystery'), 1596 – the first published defence of the Copernican system, in which Kepler demonstrated his model of the planets using geometric shapes.

Astronomia Nova ('New Astronomy'), 1609 – contains his first and second laws of planetary motion.

Harmonices Mundi ('The Harmony of the World'), 1619 – contains his third law of planetary motion.

Astronomiae Pars Optica ('The Optical Part of Astronomy'), 1604 – Kepler's exploration into eclipses, looking at the workings of light in reflection and refraction to explain astronomical phenomena.

De Stella Nova ('On The New Star'), 1606 – He wrote the book about the appearance of the supernova SN1604, also known as Kepler's Nova.

◄ In 1596 Kepler proposed that the distance relationships between the six known planets could be understood in terms of the five Platonic solids

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Build a roll-off roof garden observatory

PART 2 OF 3

How to overcome the extra footprint that is needed to support the roof runners


The runner system that supports the roll-off roof is designed to minimise disruption to a garden

Previously, the first part of our build looked at how to build the foundations, walls and flooring of our roll-off roof garden observatory, and now we are ready for the next phase, the roof.

Roll-off roof (ROR) observatories are the simplest observatories for DIY construction, but one disadvantage compared to rotating domes is the additional footprint that you need for the roof runners. If these are higher than head height, it's less of an issue because you can walk underneath them, but our observatory walls are only 150cm high, so runners would reduce the usefulness of the area they enclose. In this article, the second part of our three-part series, we're going to show how an ROR system can neatly sidestep this challenge.

By building the observatory close to a fence, the runner nearest the fence is not obtrusive and you can place potted plants below it. Our runner, which has a V-section sliding gate track on top of it, is a single length of kiln-dried timber that is continuous along the length of the observatory wall and outwards. It is supported by corner posts and a 100mm^2 fence post.

For the other runner furthest from the fence, we're using a gateleg system, keeping it as simple as possible through careful design – the less complicated it is, the less there is to maintain.


Steve Tonkin is a binocular observer who takes part in projects with The Astronomical Unit

We needed our roof to slope down to the north, but solar panels need to slope the other way. This meant that a small slope angle was essential. To prevent pooling of water, the minimum permissible slope for a roof covered with EPDM (roof membrane) rubber is 0.72°. We incorporated a small safety margin with an angle of slightly more than 1°.

We calculated that the roof, with solar panels, would eventually weigh nearly 85kg, which would be distributed along the length of the two runners. The gateleg was designed to be sufficiently robust that it securely supports the roll-off roof's weight.

The lower cladding boards overhang the walls on all sides, except where there are cut-outs for the run-off runners. This reduces the likelihood of rain or snow getting blown inside – while acting as a useful stop for the movement of the roof.

Taking precautions

A removable roof is a potential security risk, so we installed internal hold-down latches with a combined holding capacity of more than a tonne.

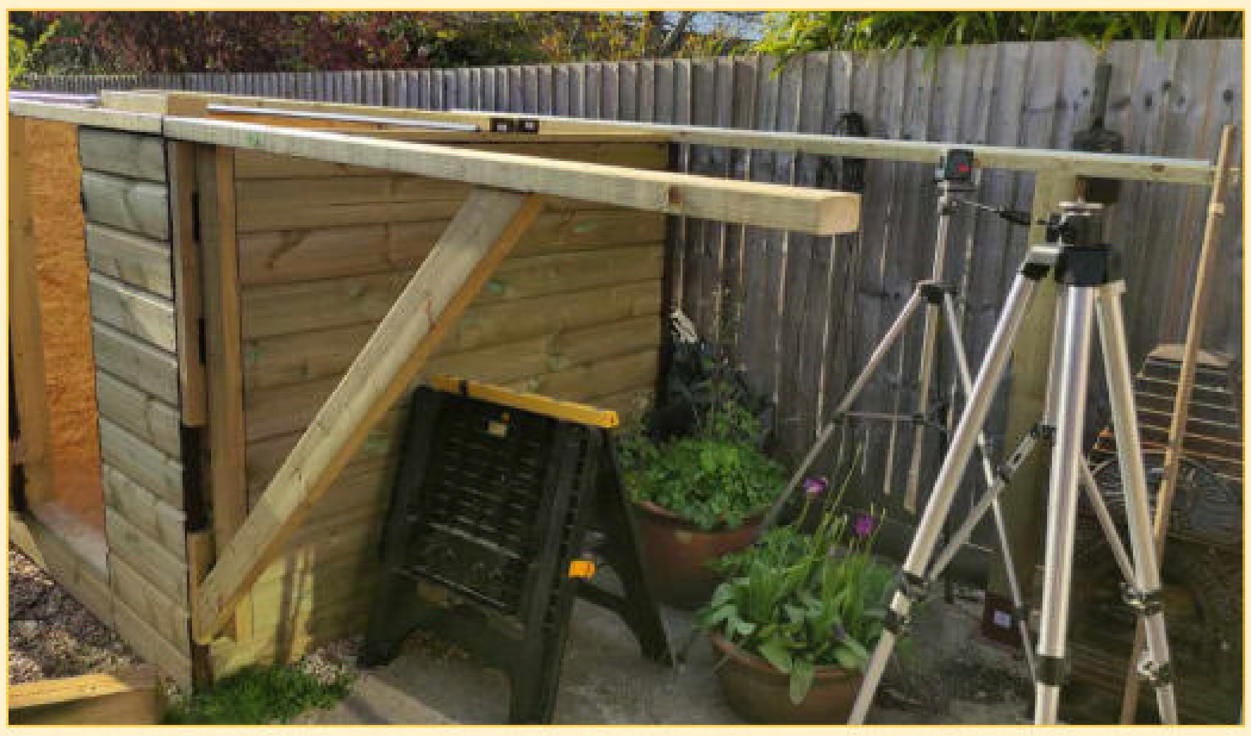
The thermal properties of a black EPDM roof covering could potentially cause big temperature changes inside the observatory. But the solar panels shade much of it and we installed insulation board between the joists. This helps to keep the inside temperature more equable to the outside.

See the step-by-step for details. Next month, we will install the low-voltage solar-PV (photovoltaics) electrical system and consider options for controlling your telescope from the comfort of your desk.

What you'll need

- Tools include: spanners (for the lag bolts) and screwdrivers; a try square; a circular saw and a jigsaw; a hammer; a drill and quick-grip clamps.
- Materials include: 9mm OSB3 orientated standard board; 95mm x 45mm kiln-dried timber and 25mm insulation board; 100mm^2 treated fence post and socket; a bolt-down sliding-gate track and six wheels; gate hinges, tower bolts and hold-down latches. Plus EPDM (rubber roofing) sheet and adhesive; an edge and gutter trim kit for EPDM roofs; assorted screws, nails and lag bolts.

Step by step



Step 1

The gateleg is built from 95mm x 45mm timber. The hinges are potentially the weakest link in this system, so make sure you get good quality ones. Use at least three hinges and use screws that go through the jambs and cladding into the corner posts.

Step 2

Connect the roof joists to the sides of the roof with lag bolts. We used rabbet (recessed) joints at the back of the roof to give a 1° slope away from the front. Two of the joists are spaced to accept the solar panel mountings.

Step 3

The roof has three wheels on each side, attached with lag bolts, which run along sliding-gate tracks. The track is narrower than the walls, so it is possible to compensate for slightly non-parallel walls. (The buffer at the end of the gateleg track is temporary.)

Step 4

A tower bolt secures the gateleg in its closed position, where it bears against the roof cladding, locking the roof closed. Another bolt holds the gateleg open and the cladding cut-out ensures that the gateleg is in the correct position before the roof can open.

Step 5

The cladding on the far side of the roof to the runners prevents it opening too far. And to ensure that the roof cladding can clear it, the top of the wall on this side is hinged and folds downwards. When this is up, it helps to lock the roof in its closed position.

Step 6

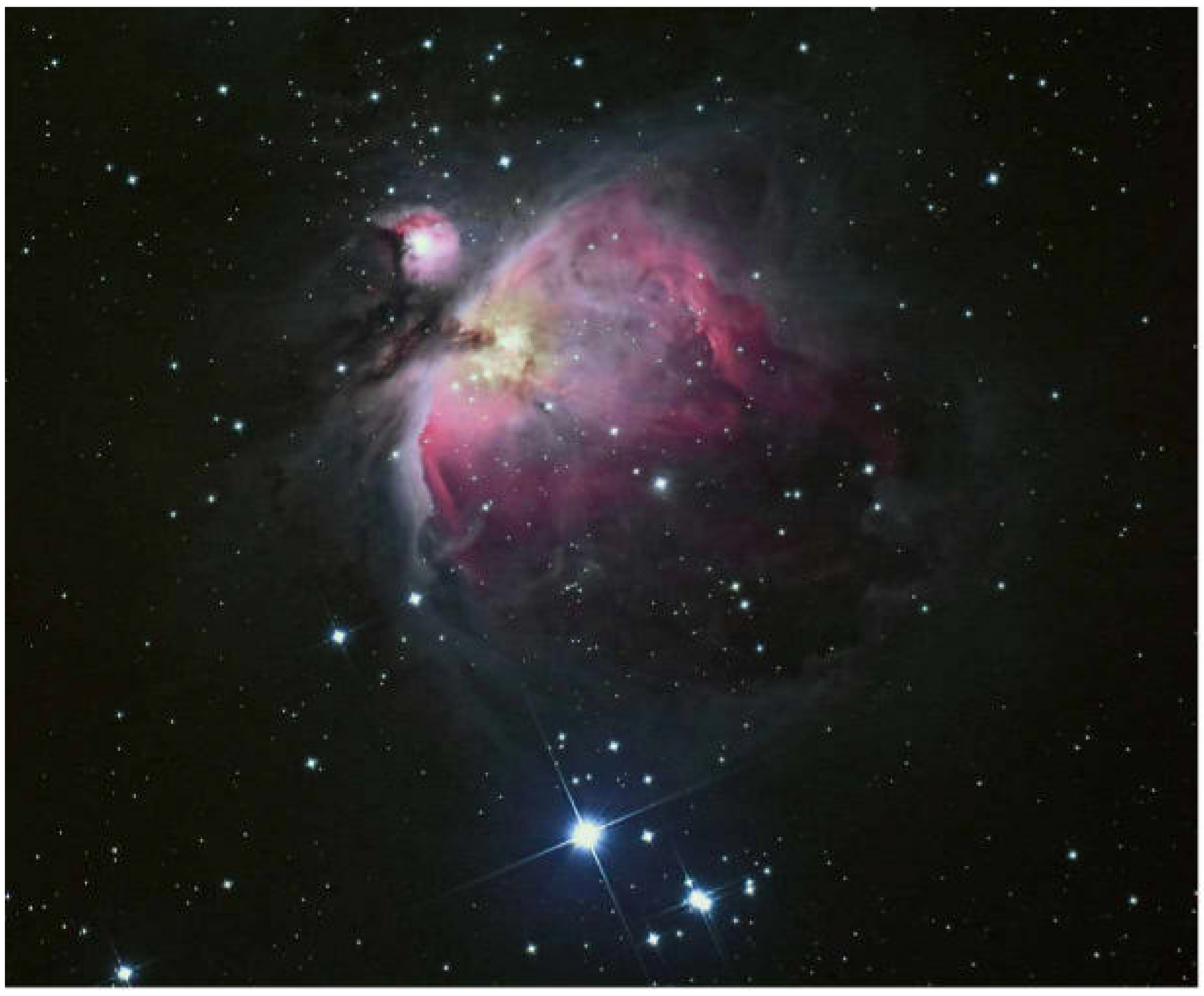
The roof deck is 9mm OSB3 (orientated standard board) sheet. We covered it with EPDM rubber roofing membrane, which lasts longer than felt and is a material of choice for low-slope roofs. After we glued it down, we secured it with gutter and edge trims.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Imaging the Orion Nebula

Test your skills by drawing out the colour, detail and objects in and around Orion's Sword



▲ **Explore the treasures of the Orion Nebula, M42, and combine your captures in a seamless image**

The Orion Nebula, M42, is a bright emission nebula in the centre of Orion's Sword. It is a popular starting point for astrophotography because it reveals how the visual greyness of most deep-sky objects becomes a wonderful colour palette when a camera is used. In this article we will show you how to explore and capture the sights in and around the nebula.

M42 has a small cluster at its heart known as the Trapezium, named after the shape formed by its four brightest stars. If you use a camera's 'Live View' mode with sufficient magnification, you will find that separating and focusing the Trapezium stars is quite easy to do.

The Orion Nebula's core, known as the 'Thrust', is kidney-shaped and brighter than its surroundings. The Trapezium lies within the Thrust. Exposing properly for the Thrust will show its mottled texture and the Trapezium stars, but the outer 'wings' (the 'Sail' and 'Sword') may look underexposed. The faint wisps of nebula that extend beyond the Sail and Sword probably won't show at all in an exposure designed to capture the Thrust. Conversely, an increase in exposure will reveal the fainter parts of the nebula but will overexpose the Thrust, losing the stars of the Trapezium in the process.

The solution is to use two or more exposures and combine the results to produce a higher dynamic-range shot than your camera can deliver in just one. Doing this in layer-based image editing software is easy, especially if it supports layer masks. The skill is combining these to look natural, disguising the fact that the result has been created from several images.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Expanding the search

After exploring the core, you can expand your sights to the surrounding area, as this is a great way to build your deep-sky imaging skills. Next to the Thrust is comma-shaped M43 and, as you head south, you will find the open cluster NGC 1980, which forms the southern end of Orion's Sword with Iota (ι) Orionis.

Head north along the Sword to the faint emission and reflection nebula NGC 1977. Long exposures reveal darker lanes passing across the glowing cloud, which resemble the outline of a running figure. This is known as the Running Man Nebula. The northern end of the Sword is truncated by open cluster NGC 1981.

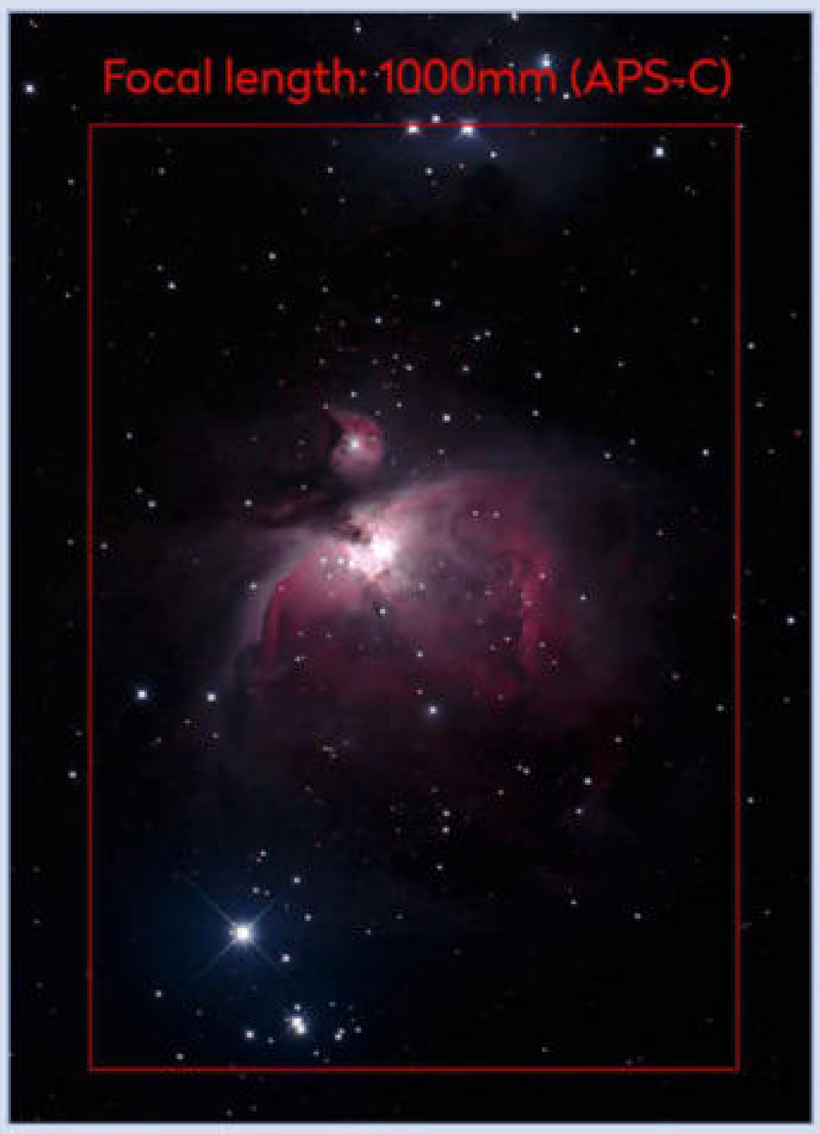
Wide-field shots of the Sword can be taken using a general camera lens. The low image scale used here will alleviate the need to have ultra-precise tracking. Close-ups of the Orion Nebula are best suited to camera-telescope combinations, where more tracking precision is required to avoid blurring.

Recommended equipment: a DSLR camera or equivalent, a general photographic lens or telescope, and a polar-aligned tracking mount

Send your images to:
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

Step by step

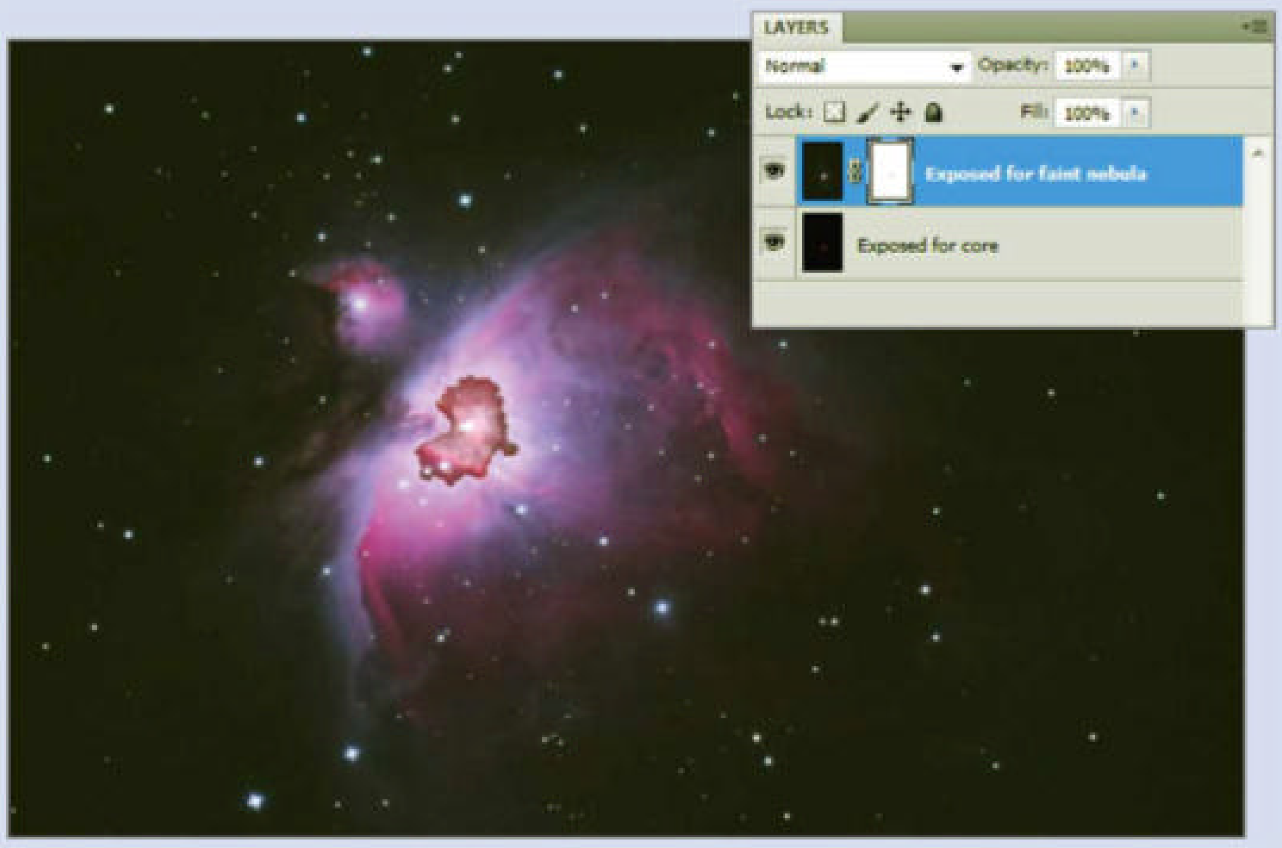


STEP 1
Decide on the type of image you want to take. A general photographic lens with a focal length of 500mm on an APS-C sensor (equivalent to an 800mm lens on a full-format camera) will capture the entire Sword region. A 1,000mm lens (APS-C) or 1,600mm lens (full-format) will get you a lovely close-up of the main nebula.

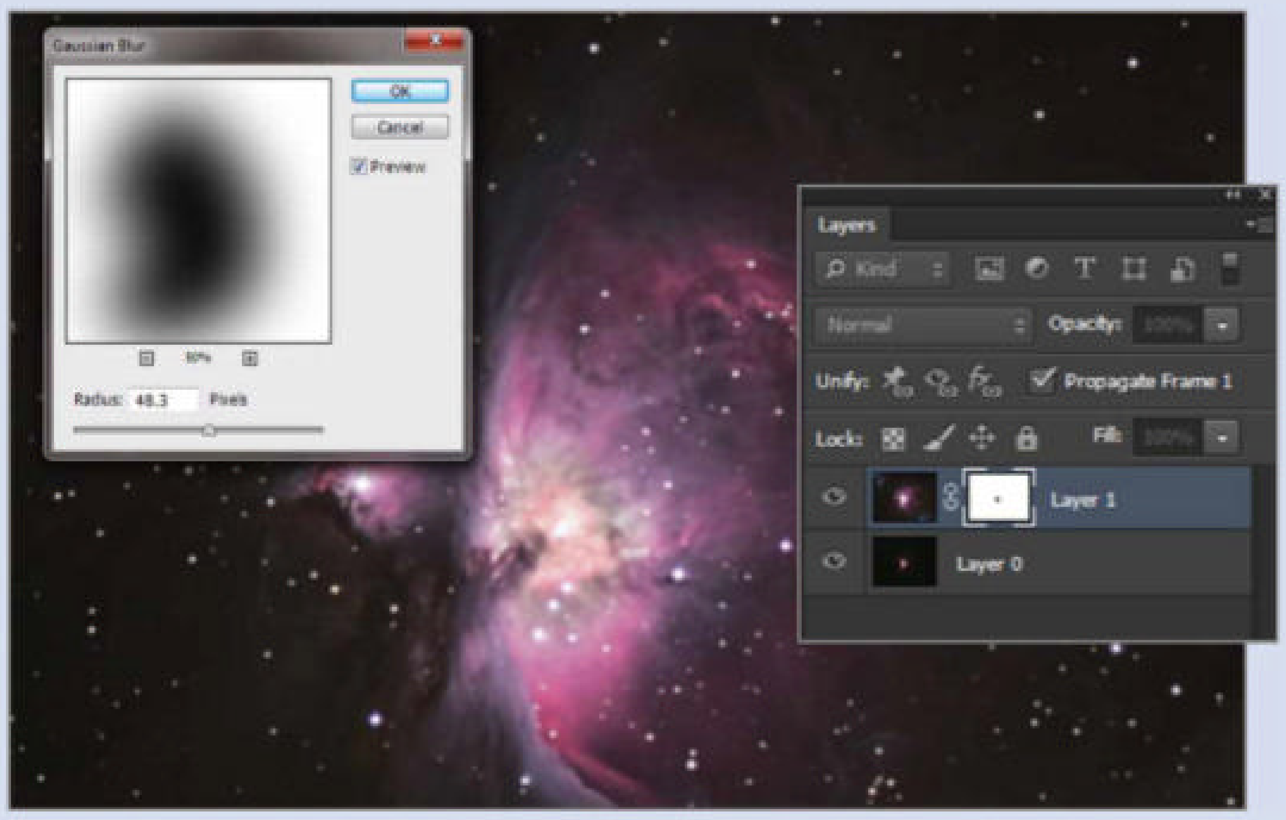
STEP 2
For a photographic lens, set the focus to manual and the aperture to wide open, closing by a couple of stops if distortion occurs at the edges. Set the ISO to a low/mid value (lower is better for nebulae close-ups with an accurate tracking mount). Using a shutter-release cable is also recommended.

STEP 3
For the best quality, use the camera's RAW format to view, open and edit images. Focus accurately – use 'Live View', if possible, on the brighter field stars. For a close-up of M42, use the Trapezium Cluster stars as targets. Take a test shot and review, adjusting exposure for the bright central Thrust region.

STEP 4
Increase the exposure time, maybe the ISO too, to capture the nebula's outer regions, while overexposing the Thrust. If you can align and stack images, take shots of each type for this purpose. Take similar shots with the lens cap for darks. These should be subtracted from the corresponding images to remove hot pixels.



STEP 5
Open the correctly exposed Thrust image. Next, cut and paste the outer region shot into the Thrust image as a separate layer. Align the layers accurately. Draw a selection around the over-exposed Thrust in the upper layer; copy and use it to create a layer mask (Alt + layer mask button) for the upper image.

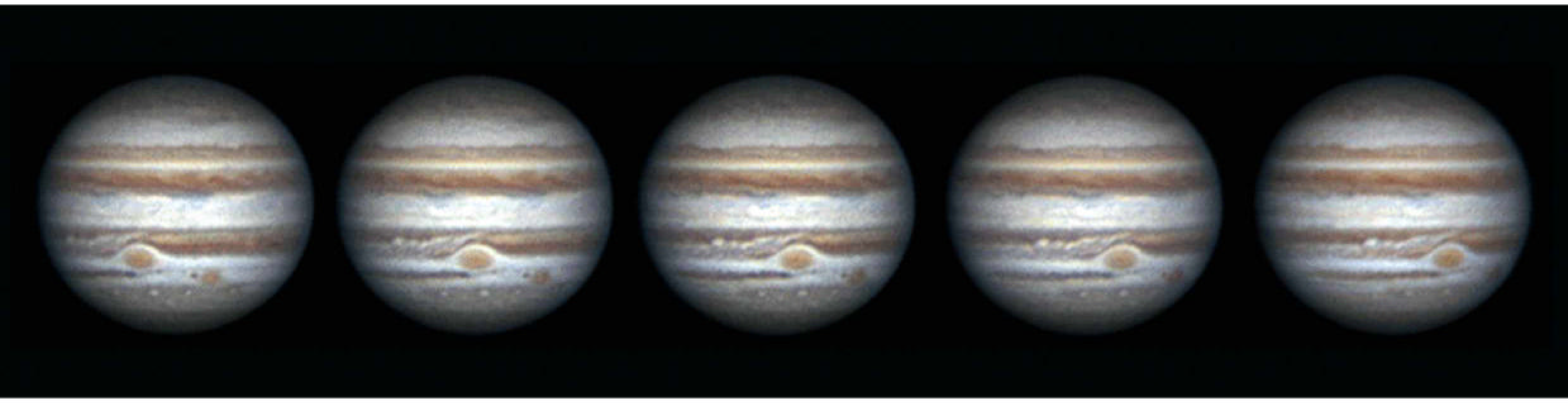


STEP 6
The correctly exposed Thrust image should show through the correctly exposed outer-region image with sharp edges. Select the layer mask, applying a 'Gaussian Blur' to it to soften the edges. Tweak the 'Curves' for both layers to achieve a smooth transition. When you're done, copy the layers, merge and save.

ASTROPHOTOGRAPHY PROCESSING

Create an animation of Jupiter

How to use photo-editing software to turn a stack of images into an animated GIF



▲ Use a sequence of your favourite Jupiter images to make a short animation of the gas giant rotating

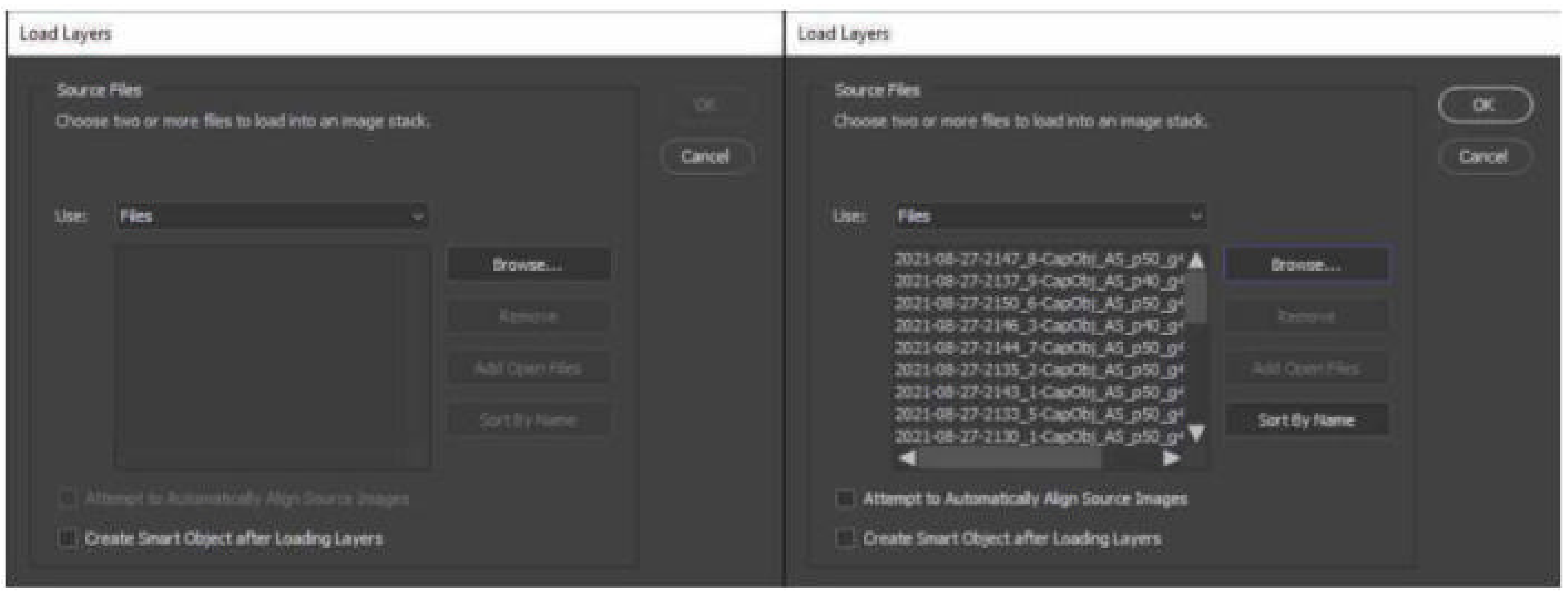
The planet Jupiter is great for capturing and presenting as an animation. The gas giant has a fast rotation period that can easily be seen and captured to create a satisfying animated GIF. This is achieved by taking individual images over a span of time, which can be less than 30 minutes. In this article we will show you how to create an animation of the rotation of Jupiter from a series of pre-processed images using Adobe Photoshop. Then, we will look at how to export it as an animated GIF, which is ideal for posting on social media, websites and for presentations.

To begin, we import the already captured and processed images into a stack in Photoshop by clicking 'File › Scripts › Load Files into Stack' from the main menu. In the 'Load Layers' panel, click on the 'Browse...' button and navigate to the folder where the processed images are stored, and select all the images required. Click 'OK' and the images will be imported into the stack (see Screenshot 1).

Once the files are loaded the 'Attempt to Automatically Align Source Images' box becomes active, so tick it and then click 'OK' at the top right. Now make the 'Layers' panel visible by clicking 'Window › Layers' from the main menu. Here, the new image stack can be viewed as a series of layers (see Screenshot 2). Using the mouse, drag each layer into time order, with the earliest image at the top and the latest at the bottom. Using WinJUPOS-compatible file-naming at the time of image capture will help with this process.

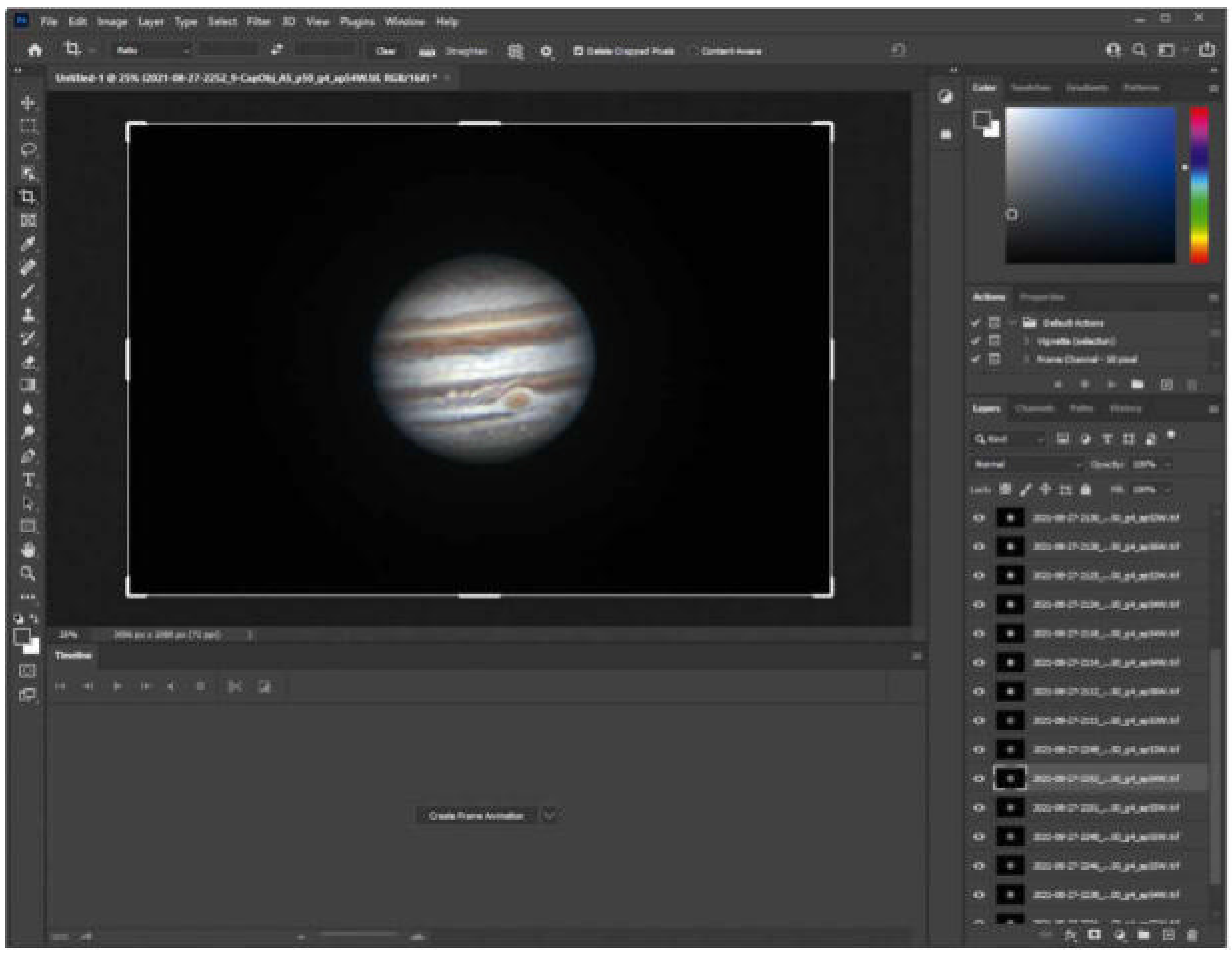
A world in motion

After the files are in the correct order, check each image and crop as appropriate to remove any blank edges created by the image alignment process. Next, open the 'Timeline' panel from the main menu by clicking 'Window › Timeline'. In the centre of the 'Timeline' panel, click the down arrow to select 'Create Frame Animation'. Double-click on 'Create Frame Animation' to create the first frame of the new



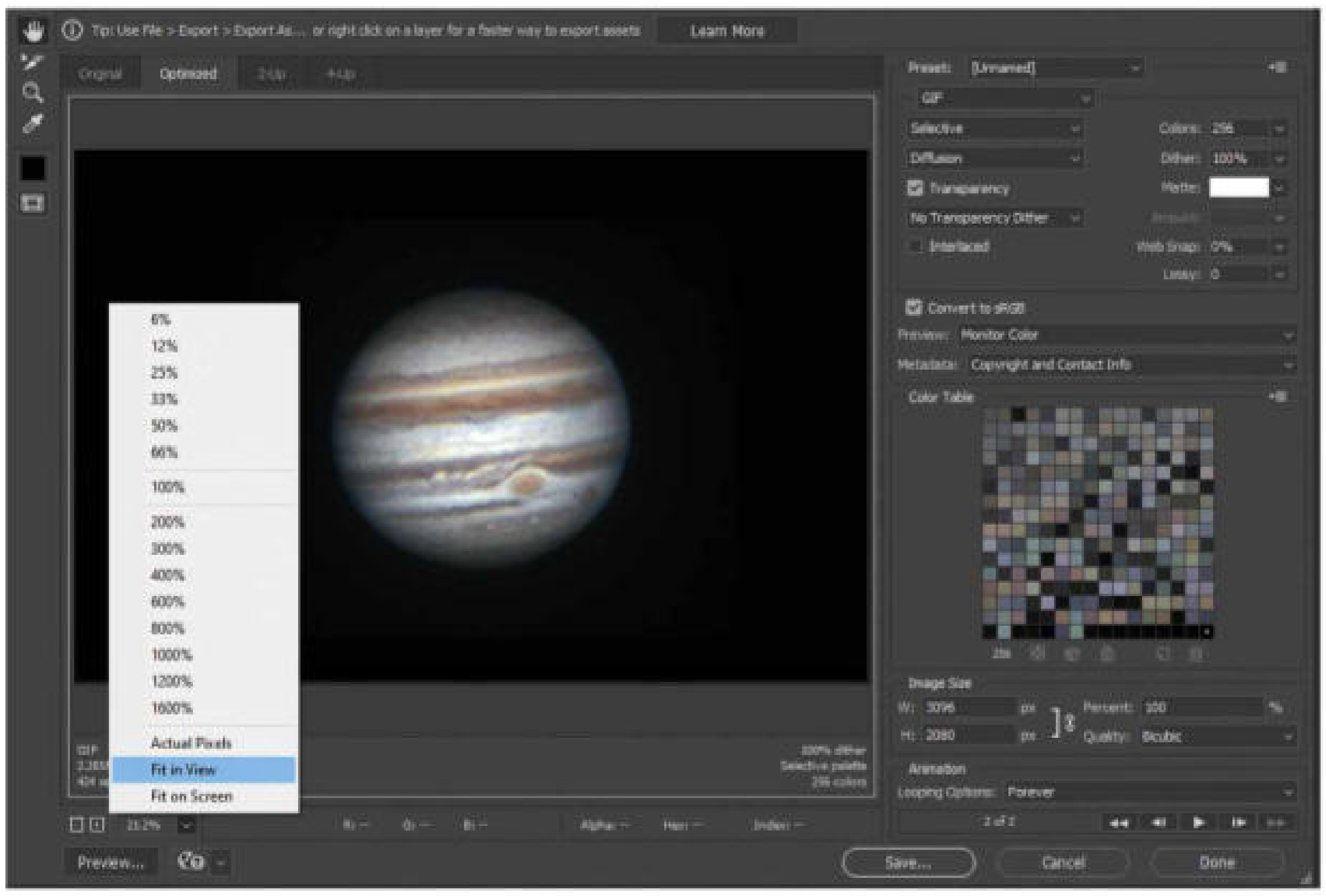
▲ **Screenshot 1: the 'Load Layers' panel before (left) and after (right) the Jupiter files have been selected using 'Browse...'. Next, click 'OK' and the files will be imported into a stack**

STEVE MARSH, DAVE EAGLE X 4



▲ Screenshot 2: the image stack can be viewed as layers in the 'Layers' panel

▲ Screenshot 3: the completed stack animation, with durations of each frame



▲ Screenshot 4: in the 'Export' screen you can make final adjustments using 'Fit in View' and then you are ready to 'Save' your animated GIF of Jupiter

3 QUICK TIPS

1. Keep consistent timings between the images being captured and it will help to produce a smoother animation.

2. Keep the camera orientation consistent when you are capturing the images – by using an equatorial mount – as any rotation in your images can make aligning them difficult.

3. Include the Great Red Spot or shadow transits by Jupiter's moons, as these always look spectacular when included in animations.

animation sequence. This can be seen in the bottom of the 'Timeline' panel.

To add the next frame in the sequence, click the square with the '+' sign at the bottom of the 'Timeline' panel. A second frame will appear beside the first one. As no changes have been made, this is identical to the first frame. To change this, go back to the 'Layers' panel and scroll to the very top of the image stack. On the top image layer, click the eye icon next to the thumbnail to hide the top image. The second image is now visible in this new frame. The animation now consists of two frames. To add the next frame, once again click the square with the '+' sign at the bottom of the 'Timeline' panel. A third frame will appear. Once again, go back to the 'Layers' panel. On the second image down in the stack, remove the eye symbol next to the thumbnail. This will now hide that image, so the third image down is visible in this third frame. Continue adding new frames in the same way, hiding each image layer until all the images have been added as frames (see Screenshot 3).

By double-clicking below each frame, you can change the duration each frame is visible for when playing, to speed up or slow down the animation. It is best to keep them all at the same timings. You can now save them as an animated GIF. To do this, select and click 'File › Export › Save For Web (Legacy)' from the main menu. If the image is not fully visible in the window, click the down arrow next to 100% at the bottom left and select 'Fit in View' (See Screenshot 4).

If the image size is big, you can reduce the size of the exported GIF by adjusting the size at the bottom right of the window. The 'H' (height) is locked to the 'W' (width) by default, so making a change to one will keep the image proportions correct. Then click the 'Save' button and scroll to the folder where you want to save the GIF and name it. Click 'Save' and you will have an animated GIF of Jupiter rotating.

Dave Eagle is an astronomer, astrophotographer, planetarium operator and writer

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

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▽ Pickering's Triangle mosaic

Paul Ecclestone-Brown, Lichfield, 28–29 August 2021

PHOTO OF THE MONTH

Paul says: "The Midlands was under almost permanent cloud cover all summer. As I ran out of data to process normally, I decided to experiment. I've been fascinated by symmetry and Newton's colour wheel, so I combined the two concepts in a single image. I took an over-stretched, starless image of the Cygnus Loop and clipped a triangular portion of Pickering's Triangle from it. I pasted that into Photoshop several times, rotating and reflecting while shifting the hue of each triangle."

Equipment: ZWO ASI294mm Pro camera, William Optics RedCat 51 refractor, iOptron CEM40 mount **Exposure:** Ha 15x 300", OIII 18x 300" **Software:** NINA, PixInsight, Photoshop

Paul's top tip: "Get confident with dedicated astro-image processors and more general packages like Affinity Photo, GIMP or Photoshop, especially in colour manipulation, layer-clipping, rotation and reflection."

Saturn and its moons ▷

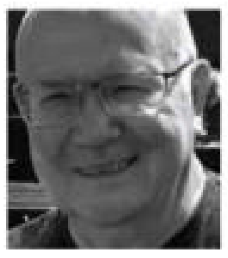
Dan Fleetwood, Rugby, 16 September 2021

Dan says: "I've always struggled to capture a crisp image of Saturn, so I was pretty pleased when I realised I'd also captured Dione, Tethys, Rhea and Titan."

Equipment: ZWO ASI290MM camera, Celestron NexStar 8SE **Exposure:** 100fps, best 20 per cent of 20,000 frames stacked **Software:** AutoStakkert!, RegiStax, Lightroom

△ Harvest Moon

Chris Duffy, Wark, Northumberland, 21 September 2021

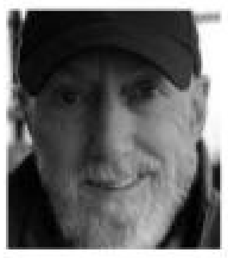


Chris says: "My equipment is suited to deep-sky imaging, but the Moon was so bright and close to the exact time of being full, I took the opportunity to take a single three-minute video."

Equipment: ZWO ASI183MM camera, Sky-Watcher Equinox 80ED refractor, Sky-Watcher EQ8 mount **Exposure:** 7,000 frames, best 10 per cent stacked **Software:** FireCapture, AutoStakkert!, RegiStax

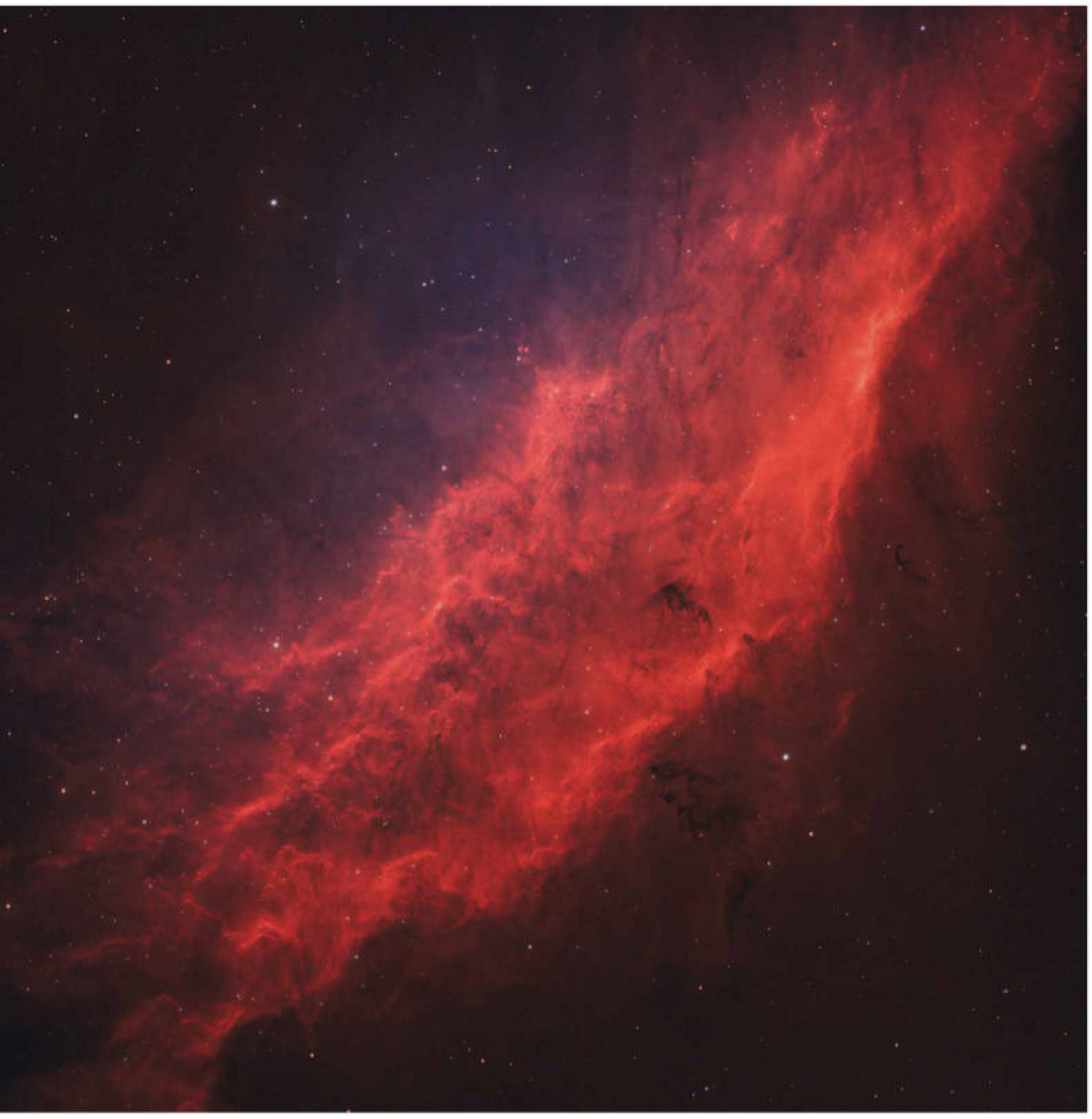
NGC 6820 ▷

Bill Batchelor, Coquitlam, British Columbia, Canada, August–September 2021



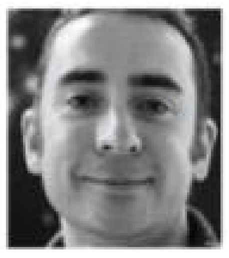
Bill says: "Because it's near other enticing targets like the Crescent Nebula, this small emission nebula is often overlooked by imagers."

Equipment: ZWO ASI1600MM Pro camera, William Optics FLT98 refractor, Celestron Advanced AVX mount **Exposure:** Ha 3h, OIII 3h, SII 3h **Software:** PixInsight, SG Pro



△ The Elephant's Trunk Nebula

Lee Pullen, Bristol, May–June 2021



Lee says: "I like challenging the conventional wisdom that OSC cameras aren't suitable for use under light-polluted skies. This was taken from Bristol city centre using an L-eXtreme filter."

Equipment: ZWO ASI2600MC Pro camera, Askar FRA400 f/5.6 astrograph, Orion Sirius EQ-G mount **Exposure:** 480x 120" **Software:** PixInsight, Photoshop, Lightroom, Topaz DeNoise AI

◁ The California Nebula

Douglas J Struble, Taylor, Michigan, USA, 21 September 2021

Douglas says: "I started capturing this nebula back in January 2018, but finally got round to reprocessing it in the HOO data palette."

Equipment: ZWO ASI1600MM camera, Stellarvue SV70T refractor, Orion Atlas Pro mount **Exposure:** 21h 26' total **Software:** SG Pro, PixInsight, Photoshop

◁ The Iris Nebula

Drew Evans, Flagstaff, Arizona, USA, 9 September 2021

Drew says: "I've been striving to capture this object for years. It took some really dark skies, three nights and nearly 18 hours of data."

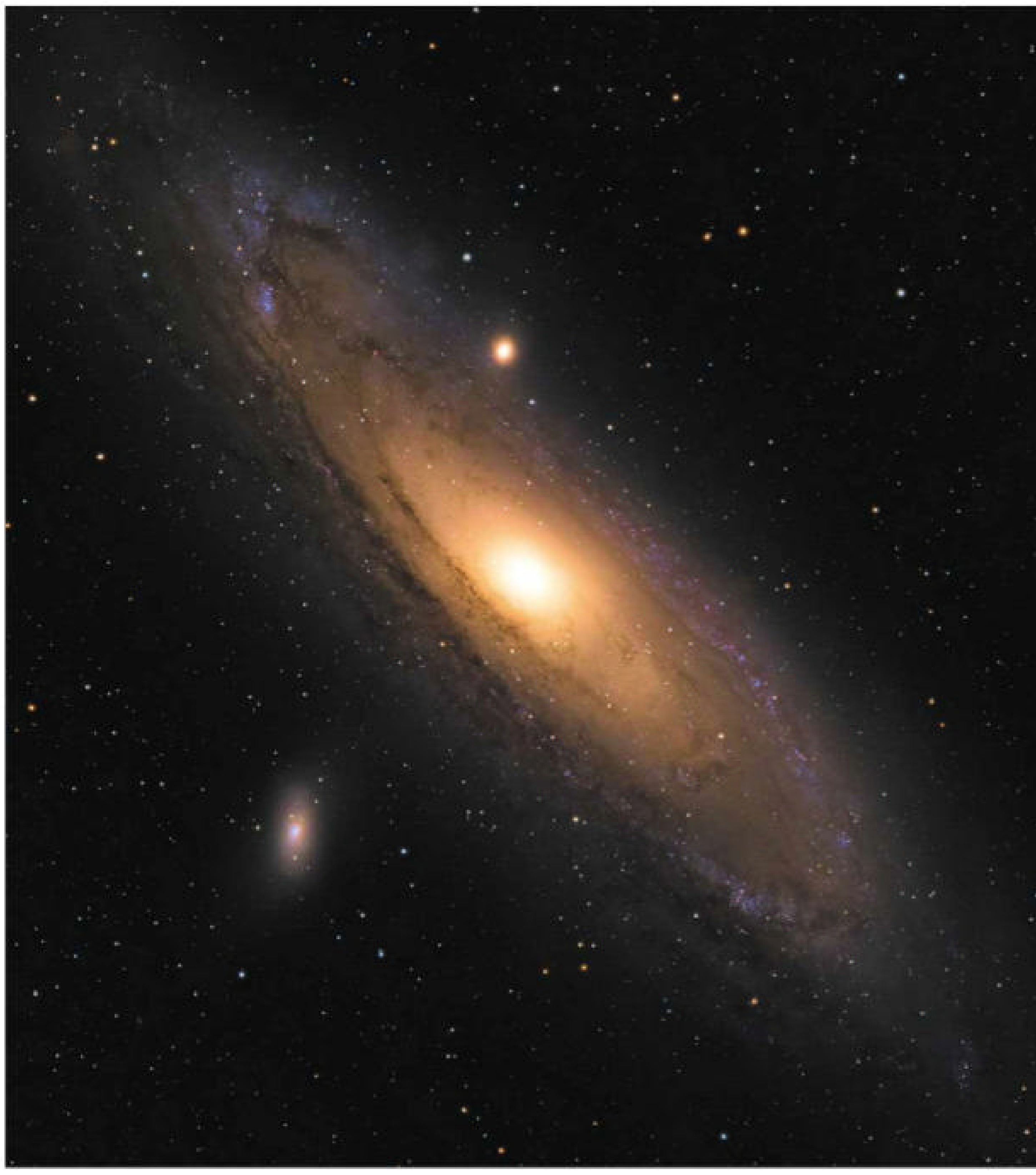
Equipment: ZWO ASI533MC Pro camera, William Optics GT81 refractor, Celestron CGX-L mount **Exposure:** 17.6h total **Software:** Astro Pixel Processor, PixInsight, Lightroom

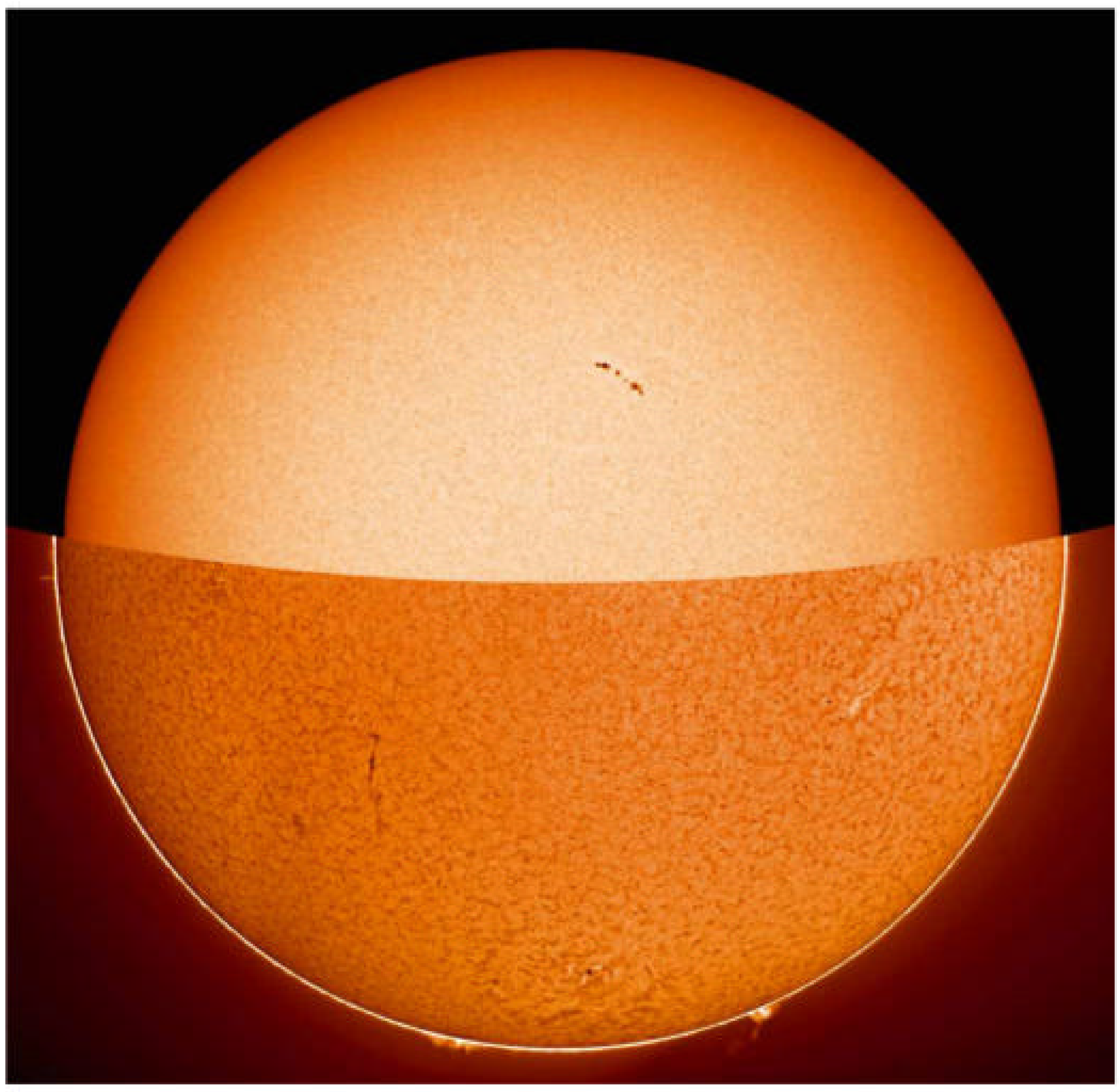
▽ The Andromeda Galaxy

Ed Holt, Beccles, 27 September 2021

Ed says: "This two-panel mosaic is the first image taken from our new home in Suffolk. We were still unpacking, but I couldn't miss the opportunity of our new darker Bortle 3 skies."

Equipment: Canon 60D DSLR camera, Sky-Watcher Evostar 80ED, Celestron CG-5 mount **Exposure:** ISO 800, f/6.3, 40x 3', 48x 3' **Software:** Astro Pixel Processor, Photoshop, StarNet++





△ The Sun in white light and H-alpha

Prabhu, Sharjah, UAE, 21 September 2021

Prabhu says: "This composite in white light (top) and Hydrogen-alpha (bottom) is a collage of 11 panels of 50 stacked frames each."

Equipment: ZWO ASI294MM Pro camera, Sky-Watcher Esprit 80mm refractor, ZWO IR/UV cut-off filter, DayStar Quark Chromosphere Hydrogen-alpha (Hα) eyepiece, Mylar ND 4.0 filter, Sky-Watcher AZ-EQ6 mount **Exposure:** 8.23ms, gain 50 **Software:** AutoStakkert!, Photoshop

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How well does the Acuter Voyager MAK80 telescope live up to being an all-rounder? We put it to the test 87

@THESHED/PHOTOSTUDIO X 3

PLUS: Books on the astronomer's chair through history and living on the ISS, and a round-up of astronomy gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good ★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

Acuter Voyager MAK80 telescope

A highly affordable, portable, all-round telescope with an effective finderscope

WORDS: PAUL MONEY

VITAL STATS

- **Price** £165
- **Design** Maksutov-Cassegrain telescope
- **Optics** 80mm (3.15-inch) primary mirror
- **Focal length** 800mm, f/10
- **Mounting** 45mm Vixen-style Sky-Watcher dovetail bar with standard ¼-inch tripod thread
- **Extras** 8x 21mm finderscope; 20mm and 10mm 1.25-inch eyepieces; star diagonal; smartphone; adaptor; carry case; giftbox
- **Weight** 1.8kg
- **Supplier** Optical Vision Ltd
- **Tel** 01359 244200
- **www.**optical vision.co.uk

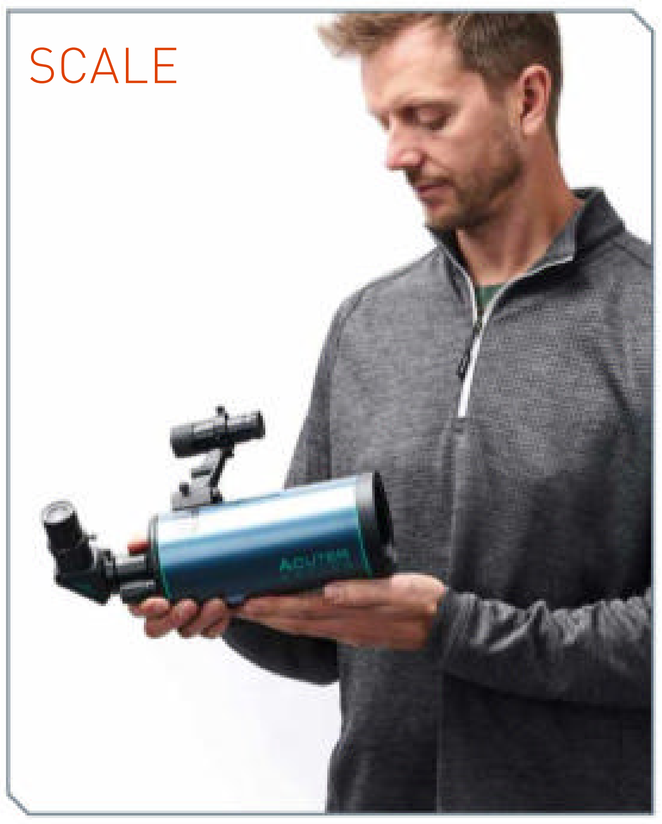
Small is beautiful, or so the saying goes, and the Acuter Voyager MAK80 certainly fits the description, even when it is still in its gift box. The instrument is a compact telescope and it is clearly well-suited for a wide range of activities, from nature and birdwatching to astronomy. For the purpose of this review, we are of course interested in discovering how well it performs for the latter.

The MAK80 is an 80mm diameter Maksutov-design telescope. Inside its tube there is a combination of lenses and mirrors that fold the path of incoming light into a compact size. This means that the focal length of 800mm fits into a tube just 270mm long. The 80mm primary mirror, combined with the focal length, gives a focal ratio of f/10.

Long focal length systems like this are known as 'slow', a term left over from the days of photographic film; it means that it's well suited for viewing the planets, Moon and double stars.

Inside the aforementioned gift box, the telescope is supplied in a soft carry case, with an 8x 21mm finderscope and two eyepieces, 20mm and 10mm, which give magnifications of 40x and 80x respectively. There is also a phase-coated 90° roof prism star diagonal and a smartphone holder. The 8x 21mm finderscope turned out to be a surprise as we normally find smaller finderscopes are quite poor quality, but this one was an exception with better optics than expected. It gave us a reasonably clear view of enough stars to help us find our targets. It is worth making or buying a dew shield, as the front lens is quite exposed to the elements.

SCALE



Accessories

The MAK80 comes with a 90°, 1.25-inch star diagonal, making it easier to look through its two eyepieces – a 20mm and 10mm – which give magnifications of 40x and 80x respectively. It also has a smartphone adaptor that holds a phone in place with rubber bands; we used it to image the Moon.

Maximising the light

In keeping with its function for both day and night use, the 90° diagonal presents an image that is the correct orientation so, unlike astronomical telescopes, the view will be upright and the image won't be reversed. It is also phase-coated to increase brightness and image contrast, which is especially helpful when you are viewing the brighter deep-sky objects that need as much light as possible to get to your eyes.

The Acuter Voyager MAK80 is an optical tube only, so you need to mount it and two options are ▸

Optics

The optics are a Maksutov design with a concave 80mm primary mirror and a convex front corrector lens that also houses the secondary mirror cell. The front corrector lens is fully multi-coated to reduce glare and allow better light transmission, while the secondary mirror is fully baffled to prevent stray light.

Finderscope

The finderscope gives a magnification of 8x and is constructed primarily of plastic. It can be easily aligned with the scope's main view by using thumbscrews. The arm on its adaptor has an integrated sight hole for initial alignment.

Focuser

Focusing is carried out with a knob at the back of the telescope, close to the eyepiece end of the system and very convenient. Adjustments move the primary mirror back and forth, and we found the action smooth with little play.

Lightweight and portable

The MAK80 is, by design, a compact lightweight system. It folds a light path (focal length) of 800mm into a tube that's only 270mm long including the eyepiece holder, with a diameter of only 100mm. The whole thing weighs 1.8kg, and will sit in the palm of your hand without hurting your wrist.

All this makes it a portable system that just requires the addition of a tripod, for which there's a ¼-inch tripod thread included in the Vixen-style mounting bar. This bar enables you to attach it to a mount, either a basic altaz tabletop variety or a star-tracking mount for prolonged use. Being so light and compact makes it ideal for taking on holiday, as a spotting scope for daytime or night-time use; the light carry case is ideal for this system, as it is compact and lightweight – perfect for taking on a plane or train as hand luggage.


A full Moon taken with the MAK80 telescope and an iPhone XR

Carry case and gift box

A soft carry case protects the Voyager when it's being transported or stored. It has several sections for accessories with room enough for a couple of extra eyepieces as well as all the supplied items.

KIT TO ADD
1. Fotomate VT-5006 tripod
2. Sky-Watcher x2 Deluxe Barlow
3. Dual LED flashlight

▸ available. The first is the Vixen-style mounting bar for attaching to a telescope mount; the second is the ¼-inch tripod thread on the underside of the bar for attaching to a standard photo tripod. We used it in both setups on our tripod, while also using our Sky-Watcher Star Adventurer tracking mount to allow for longer, more comfortable viewing without the target drifting out of our field of view.

We observed Altair (Apha (α) Aquilae) with the 20mm eyepiece, and found that the star was pin-sharp across most of the field of view. There was some slight degradation towards the edge with a little chromatic aberration (an effect usually seen as unwanted coloured rings around brighter objects), but this wasn't excessive. Turning to Saturn and Jupiter we swapped between the two eyepieces as we studied them. With the 20mm, Jupiter's disc had a hint of two belts and the four moons were well seen; when we upped the magnification using the 10mm eyepiece we got a better view of the giant planet's belts, with hints of subtle detail in the northern belt evident. Saturn was naturally smaller, being further away, but the rings were easily seen with the 20mm eyepiece and we spotted at least two moons, while the higher magnification of the 10mm eyepiece gave a good hint of the two main rings, A and B, being separated by a thin line, the Cassini Division.

Bringing out details

Although the Moon was full, it was fascinating to view its ray features, with crater Tycho and the main basins standing out. A few nights later there was crisp detail in the craters on view, although with the 20mm there was a little hint of a bluish fringe to the edges of the Moon when slightly off-axis. With darker, Moonless skies we were able to take a tour of the brighter Messier objects, ranging from galaxy pair M81 and M82, to the Dumbbell Nebula, M27, and a faint Crab Nebula, M1. Star clusters such as M39, M35, the Double Cluster and the Pleiades were visible, proving this little scope's credentials as an all-rounder. Overall, we enjoyed our time with the MAK80.

VERDICT

Assembly	★★★★★
Build & design	★★★★½
Ease of use	★★★★★
Features	★★★★
Optics	★★★★½
OVERALL	★★★★½

Bresser 10x50 Corvette binoculars

An upgraded, robust pair of waterproof binoculars that are well-suited to stargazing

WORDS: STEVE TONKIN

VITAL STATS
- **Price** £115
- **Optics** Fully multi-coated
- **Aperture** 50mm
- **Magnification** 10x
- **Prisms** Porro, BaK-4
- **Angular field of view** 6°
- **Focusing** Centre focus
- **Eye relief** 16mm
- **Interpupillary distance** 57mm-72mm
- **Weight** 940g
- **Supplier** Telescope House
- **Tel** +44 (0)1342 837098
- **www.**telescopehouse.com

Bresser's Corvette 10x50s have been well regarded as a general purpose pair of binoculars for some years. And they have now undergone a thorough 'makeover', including significant modernisation, which makes them essentially a new model. When you first take the Corvette 10x50s out of the box, you'll immediately notice the substantial feel. This is partly due to the weight, at 940g, but a lot of what is plastic on budget binoculars is metal on these. There is a selection of useful extras, including a nylon case, a 25cm-wide neck strap, a pair of tethered lens caps for the objective lenses, a tethered rain guard to protect the eyepieces, a microfibre cleaning cloth and an instruction booklet.

The wide centre-focus wheel and right eyepiece dioptre of the Corvette 10x50s are covered with rubber – with the texture and classy appearance of black-anodised knurled metal – and this allows you to have a good grip with either gloved or bare hands. Along with the central hinge, these parts move smoothly, without any stiff spots. The twist-up eyecups, on the other hand, are quite stiff, but this has an advantage; they don't have click stops for different positions, but the stiffness means that they will stay put at whatever position you set them. The cups are quite wide, though, so at the minimum interpupillary distance of 57mm (the distance between the pupils of your eyes), there is only 13mm between them, which may be too tight for some broad-bridged noses.

Protected optics

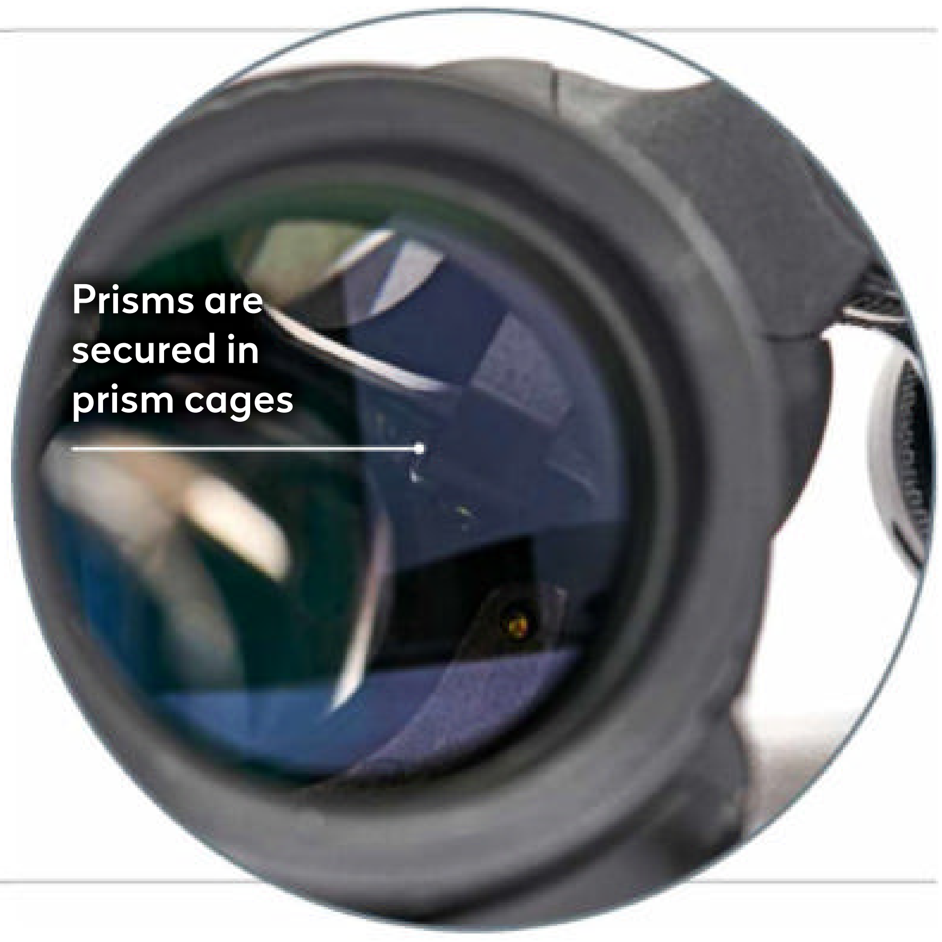
The objective lenses are set back into their cells by 11mm, which offers protection against bumps, while also reducing the likelihood of accidentally touching them. Although the clear aperture is 52mm, this is internally stopped down to an effective aperture of 46mm. This is usually done to sharpen the image at the expense of a slight loss of brightness.

When you shine a light into the objective lens, the reflections you see are consistent with the fully multi-coated specification. Although the objective tubes are ribbed, the entrance to the prism assembly and the prism cages themselves are unblackened, which resulted in some contrast-reducing stray-light scattering when the Moon was on the edge of the field of view. We also used the Moon to test chromatic aberration – an effect usually seen as unwanted coloured rings around brighter objects. It is generally well controlled, with only a small amount ▸

Robust construction

The recent fashion to make binoculars as lightweight as possible comes at the expense of robustness. Fortunately, Bresser has not fallen into this trap with the updated Corvette 10x50s, which retain the rugged characteristics of earlier models. They boast a metal Bausch & Lomb-style body, which means that the prism housing and objective tube is a single casting for each side, so there are no separate objective tubes. The body itself is covered with a 2mm-thick rubber armour, which gives ample protection against everyday use. Many centre-focus binoculars suffer from a rocking eyepiece bridge, which can make them difficult to focus precisely, but this bridge is rock-steady in normal use.

Bresser has also shunned the fashion for having the prisms held in their housings with clips, which leaves them liable to shift at even a slight knock. The prisms of the Corvette 10x50s are held in a proper prism cage, an altogether more robust design.




SCALE

Precise focus

Unusually, it takes one and a half rotations of the centre-focus wheel to go from one end of the focal range to the other. But this slow focusing makes it easy to achieve the precise focus that is essential when you are using binoculars for astronomy.

Waterproof and inert gas filled

Due to their nocturnal use, it is usual for astronomical binoculars to become damp with dew. If this moisture gets inside it can cause corrosion of metal parts and allow algae and fungus to grow on the optics. Waterproofing is the first line of defence, and the inert gas filling reduces the likelihood of damage from moist air.

Tripod-mountable

For 10x50s, these are quite a heavy pair of binoculars, so you might want the option of mounting them for a long stargazing session. Under a cover at the end of the hinge you will find a standard ¼-inch Whitworth mounting bush for an optional tripod adaptor.

FIRST LIGHT

Tethered lens caps

We particularly liked the tethered lens caps. They fit extremely well, so they won't fall off when you use them. Being tethered, you won't lose them and they're always where you need them when you want to keep dew or dust off your lenses.

Anti-reflective coatings

We astronomers loathe losing light, so we want to ensure that whatever we capture makes its way to our eyes. Anything that is not reflected from the surface of a transparent element must be transmitted, so effective anti-reflective multi-coatings enable us to receive a maximum amount of the captured light.

▸ visible at the centre of the field of view; even near the edge it was unobtrusive.

The precise focusing system on these binoculars is ideal for astronomy. Our test showed that stars in the middle of the field of view snap to an obvious best focus, but those near the edge are degraded, mostly due to mild field curvature. We were able to keep the components of the double star Albireo (Beta (β) Cygni), with 35 arcseconds separation, split within the central 75 per cent of the field of view. We found that the colour rendition was good in the large sweet spot in the middle of the field of view, but nearer the edge the colours started to become washed out. Meanwhile, Jupiter showed a distinct disc and all four of its Galilean moons were visible when they were away from the gas giant's glare.

Views of the deep sky

Binoculars of this size excel on the larger open clusters and asterisms, and this was borne out by the lovely views we had of the Alpha Persei Cluster (Collinder 39) in Perseus, Kemble's Cascade in Camelopardalis, and Eddie's Coaster in Cassiopeia. Looking southwest, we could hold IC 4756 and NGC 6633 in the same field of view and we could appreciate the contrast between these two fine open clusters. Once it rose above the neighbour's roof, the Andromeda Galaxy, M31, looked magnificent in a crisp, moonless sky, and we could just make out its two faint companion galaxies. Later, we tried the Triangulum Galaxy, M33, but this proved to be more difficult and appeared merely as a small region of slightly brighter sky.

Although these binoculars are quite heavy, at 940g, they're not uncomfortably so. They have a good balance, especially when you are gazing skywards, so extended hand-held observing stints are possible, especially if you observe while you are reclined.

Overall, the Bresser 10x50 Corvette will appeal to someone who wants a rugged, moderately-priced general-purpose pair of binoculars of decent quality, which will also be very useful for astronomy.

KIT TO ADD

1. Bresser TR-688V video tripod with two-way tilt

2. Bresser binocular metal tripod adaptor SFM-1

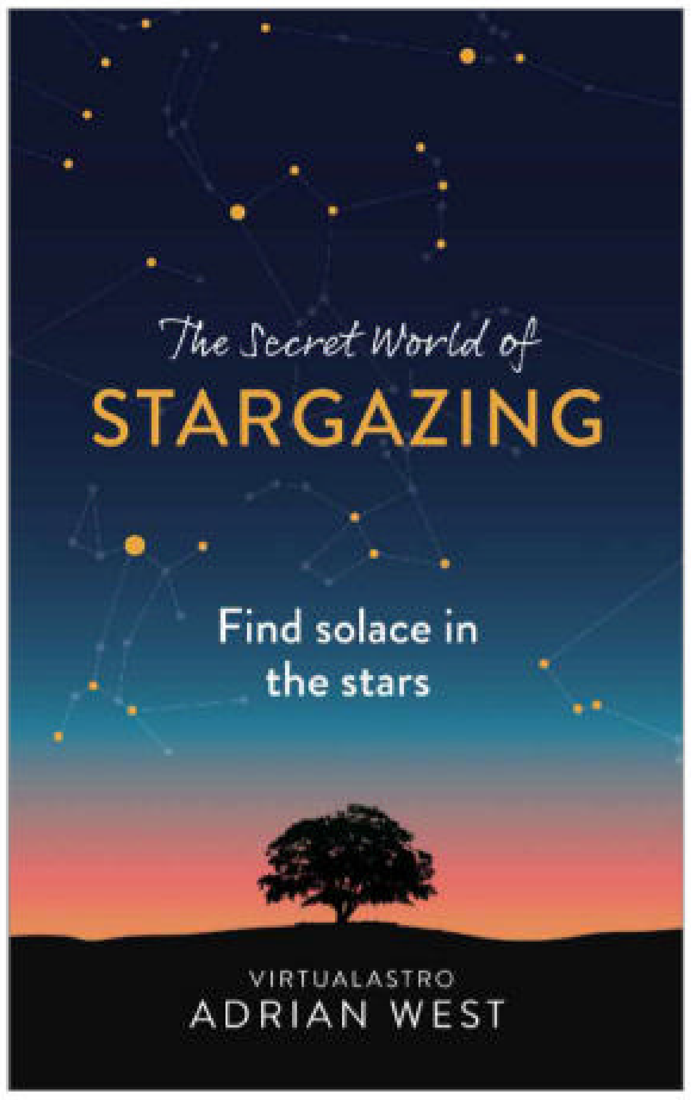
3. Explore Scientific Solarix solar filter film for DIY Sun filters

VERDICT

Build and design	★★★★½
Ease of use	★★★★½
Features	★★★★½
Field of view	★★★★
Optics	★★★★
OVERALL	★★★★½

New astronomy and space titles reviewed

BOOKS



The Secret World of Stargazing

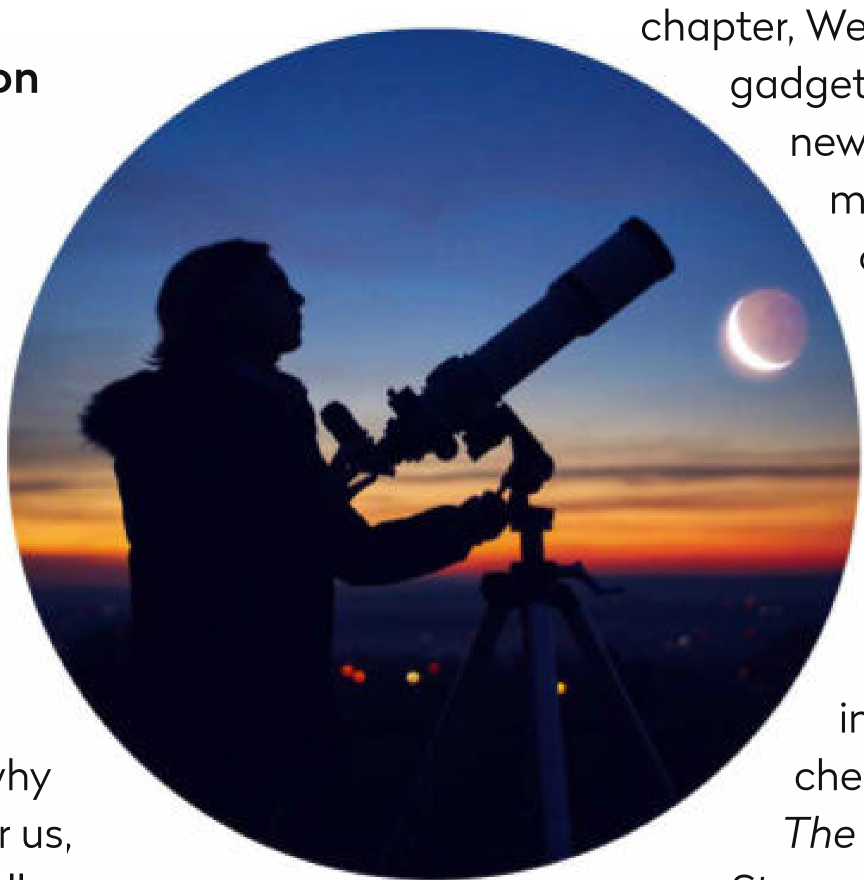
Adrian West
Hodder & Stoughton
£14.99 ● HB

The Secret World of Stargazing will resonate with so many of us. Adrian West has produced a charming book with a strong emphasis on wellbeing: how and why stargazing is good for us, physically and mentally.

Having lost a close friend last year, I spent a lot of time under the dark, clear sky whenever I could. It was a time for thinking, being alone and enjoying a connection with our natural world, the sky and sounds of nature. West focuses on these points in his book, and he does it in an uncomplicated way that we can all enjoy and empathise with.

This is very much a book for anyone who is just starting out and finding their stargazing feet for the very first time or, as West says, for anyone with a passing interest. There is no jargon to confuse or put the novice off and West makes that very clear from the outset. Indeed, as so many guides these days affirm, with West being no exception, stargazing is for everyone. You can make it as cheap or expensive as you like, and you can even enjoy the night sky in light-polluted areas and it needn't be difficult.

West takes the beginner through the basics, from all-important advice about clothing and what each season has to offer, to Moon phases and meteor showers, asteroids and comets. Prominent, seasonal constellations to observe in both hemispheres are explained, all the while entwined with stories from mythology. The book could have benefited from more illustrations, but beginners will certainly gain an understanding of the Solar System and what they are looking at when they gaze up to the sky. In the last chapter, West describes the gadgets available for newbies who want to move from naked-eye observing to a magnified eye.



Adrian West's book will entice newcomers to astronomy, with vital tips about the dos and don'ts

M-GUCCI/ISTOCK/GETTY IMAGES

He has concisely embraced all the important points, including starting off with binoculars and how not to fall into the 'buying a cheap telescope trap'.

The Secret World of Stargazing is a lovely book. It is personal, delicate and beautifully innocent. For those more experienced astronomers, it is a reminder of why so many of us immerse ourselves in the hobby, and for those just starting out, it is a useful leg-up onto the first rung of the stargazing ladder. ★★★★☆

***Katrin Raynor-Evans** is a Fellow of the Royal Astronomical Society and an astronomy writer*

Interview with the author
Adrian West

When did you catch the stargazing bug?

I have always been fascinated by the night sky. From a very young age I can remember seeing the stars shining bright above me as my parents walked us home from my grandparents' house. My interest grew through science fiction, especially *Star Wars* and *Star Trek*.

Does social media particularly suit astronomy outreach?

It's one of the best ways of bringing astronomy to the masses. People can take as little or as much as they want. Teaching astronomy conventionally can sometimes be overwhelming for those with just a passing interest or who aren't scientifically minded.

What top tips would you give to beginner astronomers?

Take your interest at your own pace, in a way that you enjoy. Follow some astronomy people on social media. Read some popular guides and books, or even join a club. Enjoy the night sky your way, whether that's emotionally, creatively, scientifically, or just because it's there. The night sky and the Universe beyond is for everyone to enjoy.

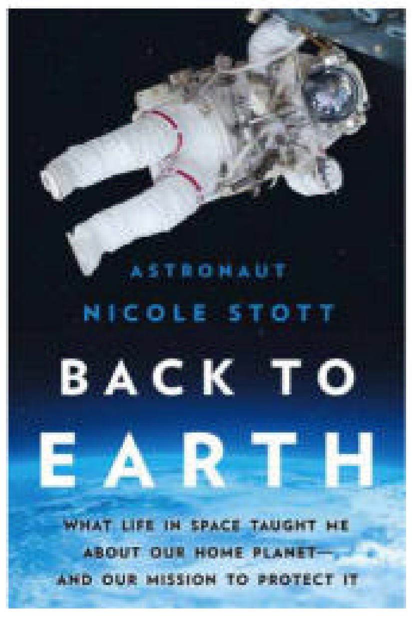
What are you looking forward to in 2022?

I look forward to the changing seasons and everything within. Sunsets, the movement of the sky, the phases of the Moon, meteor showers, spacecraft, planets – I look forward to it all, and sharing the night sky with others. But the thing I am looking forward to most is simply relaxing under the stars, just taking it all in.

***Adrian West** is best known as VirtualAstro on social media and for his Night Sky Show live events*

Back To Earth

Nicole Stott
Seal Press
£25 ● PB



During her 27 years working as a NASA astronaut, Nicole Stott spent 18 days living on the ocean bed (in the Aquarius Reef Base underwater habitat) and more than three months living aboard the International Space Station (ISS).

Seeing our home planet from space has given Stott a unique perspective. She sees Earth as a perfect life support system, providing everything we need to survive and thrive with only our thin atmosphere shielding us from the lethal space beyond. In *Back To Earth*, the former astronaut likens our planet to a spaceship and calls for each of us to stop being mere passengers, but to take responsibility for our survival. As full crew members, our mission is to work together to keep our spaceship running smoothly.

Her book takes the work done on the ISS, and the protocols and training that its inhabitants use, as models for meeting the challenges of climate change on Earth.

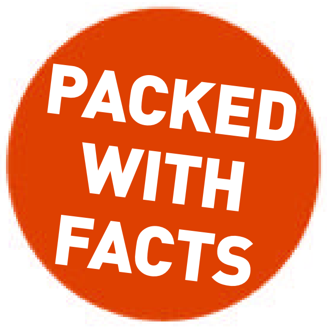
It showcases the work of various individuals, companies and organisations that are working to make a difference, from funding clean water projects around the world to re-growing coral reefs. Stott reveals that even entire communities (such as the Isle of Man) are working with local businesses to make their environment more sustainable.

The author also shows practical changes that we can make to our own lives, as individuals, that will improve the planet as a whole.

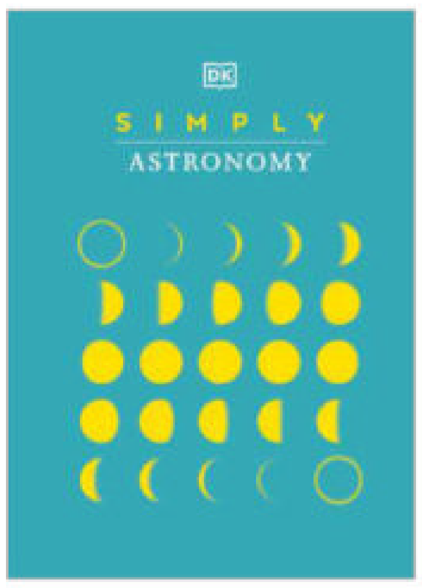
Both inspirational and down to earth, with a 'can do' attitude that is empowering, this is a hopeful and beautifully written call to roll up our sleeves and work together as crew mates on our shared spaceship Earth.
★★★★☆

***Jenny Winder** is a freelance science writer, astronomer and broadcaster*

Simply Astronomy



Various
DK
£9.99 ● HB



"Sometimes less really is more," the authors of *Simply Astronomy* proudly proclaim on the back-cover blurb of this little gem of a book. Penned for Dorling Kindersley by an enthusiastic group of physicists, astronomers and science writers, its bite-sized chapters look in turn at the building blocks of the Universe we inhabit, our Solar System home, the stars, galaxies and constellations that we see when we crane our necks upward, and how we can play our own small part in understanding the cosmos.

Bright and colourful from cover to cover, this book is nowhere dry or dull. Its targeted audience demographic is almost as broad as its subject matter. In fact, *Simply Astronomy* could be just as handy in a school classroom as in an undergraduate astronomy library or the popular science section of a high street bookstore. It is nothing less than a compact one-stop-shop for this most ancient of sciences.

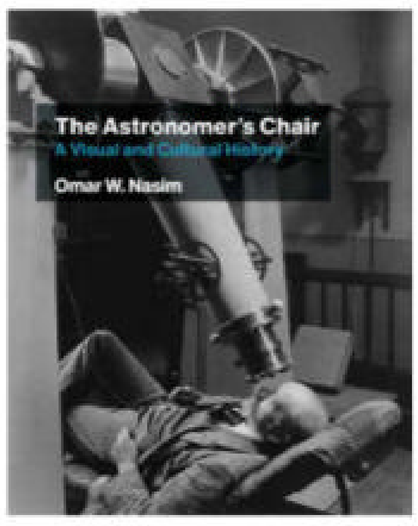
What makes *Simply Astronomy* work is that the authors have cleverly kept their prose to a minimum – less really is more, after all – and allowed diagrams and easy to follow infographics to visually tell their story. Complex topics are condensed into chunks that are a couple of pages long at most, affording the reader just enough to pique the interest.

But despite its sparseness of language and indulgence of imagery, the book is accurate, comprehensive and impressively up to date. It packs a refreshingly sizeable punch for its diminutive size. ★★★★★

***Ben Evans** is the author of several books on human spaceflight and is a science and astronomy writer*

The Astronomer's Chair

Omar W Nasim
MIT Press
£52 ● PB



In faded engravings of whiskered Victorian 'gentlemen astronomers' you can often spot a little-noticed item of furniture: the astronomer's chair. Now demoted to a curiosity of history (at least to professionals and high-tech amateurs), these reclining, swinging and rotating mechanical devices have been variously described as instruments of torture, death traps, essential laboratory equipment or saviours of science. Their design, adaptation, method and history have often been neglected in the annals of astronomy.

This richly illustrated book goes some way to rectify the oversight by surveying the social and cultural history of this apparently mundane article of furniture, from medieval times to the early modern era. However, rather than mere description, the volume hinges on the argument that these devices embodied perceptions of gender, race, class, even imperialism, Westernisation and the bourgeoisie.

The volume is a substantial academic thesis, documenting a rigorous and exhaustive research project, but is, unfortunately, not one of much interest to the amateur astronomer, and arguably not the professional either. There are some interesting historical and anecdotal passages concerning astronomical pursuits, their advocates, instruments and methods of observing, but these are few and far between. The vast majority of the book pertains to the social and cultural history of the chair as a piece of furniture, with a highly-developed scholarly hypothesis then applied to 'scientific' chairs of various kinds. As a sociocultural theory of chair design, and its implications, the book stands up well, but as a history of science it sadly fails. ★★⯪☆☆

***Alastair Gunn** is a radio astronomer at Jodrell Bank Observatory in Cheshire*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 ZWO OAG-L M68 off axis guider

Price £191 • **Supplier** Widescreen Centre
www.widescreen-centre.co.uk

Off axis guiders (OAGs) help to ensure that your astrophotography setup remains on target and crisp. This OAG comes with a large 12mm x 12mm prism, giving a wider field of view and a more stable image.

2 Explore Scientific OIII 1.25-inch nebula filter

Price £125 • **Supplier** Telescope House
www.telescopehouse.com

This filter helps to reduce the effects of artificial light and increase contrast on deep-sky objects by only letting in the specific wavelength of light given off by oxygen. Alternatively, it can be partnered up with other filters, like SII (silicon) and Ha (hydrogen-alpha), for multi-band astrophotography.

3 Ion8 food flask for hot food (large)

Price £21.99 • **Supplier** Ion8 • **www.ion8.co.uk**

A long night of observing can be hungry work, and a hot meal helps to keep your spirits up. This flask keeps your food warm for up to six hours, and comes with a built-in spoon and compartments for extra snacks.

4 Samantha Cristoforetti Barbie

Price €34.99 • **Supplier** ESA
https://esaspaceshop.com

ESA astronaut Samantha Cristoforetti, who has long been an inspiration to the next generation of space farers, is now being honoured in doll form by Barbie's role model series. Mini-Samantha is dressed ready for a spacewalk, complete with a helmet and insignia.

5 North Ridge resistance long sleeve base layer

Price £20 • **Supplier** Millets • **www.millets.co.uk**

Regulate your temperature during long observing sessions with this base layer. The mesh side panels offer extra breathability to help you stay dry when working up a sweat during setup so you don't get cold during the night. Available in sizes for men and women.

6 Asterion Cooler Cat

Price £109 • **Supplier** First Light Optics •
www.firstlightoptics.com

Closed tube telescopes, such as Schmidt-Cassegrains or Maksutovs, can trap unstable air inside and take a long time to cool. This device slots inside the tube to circulate air from outside and reduce the amount of time it takes to reach thermal equilibrium.

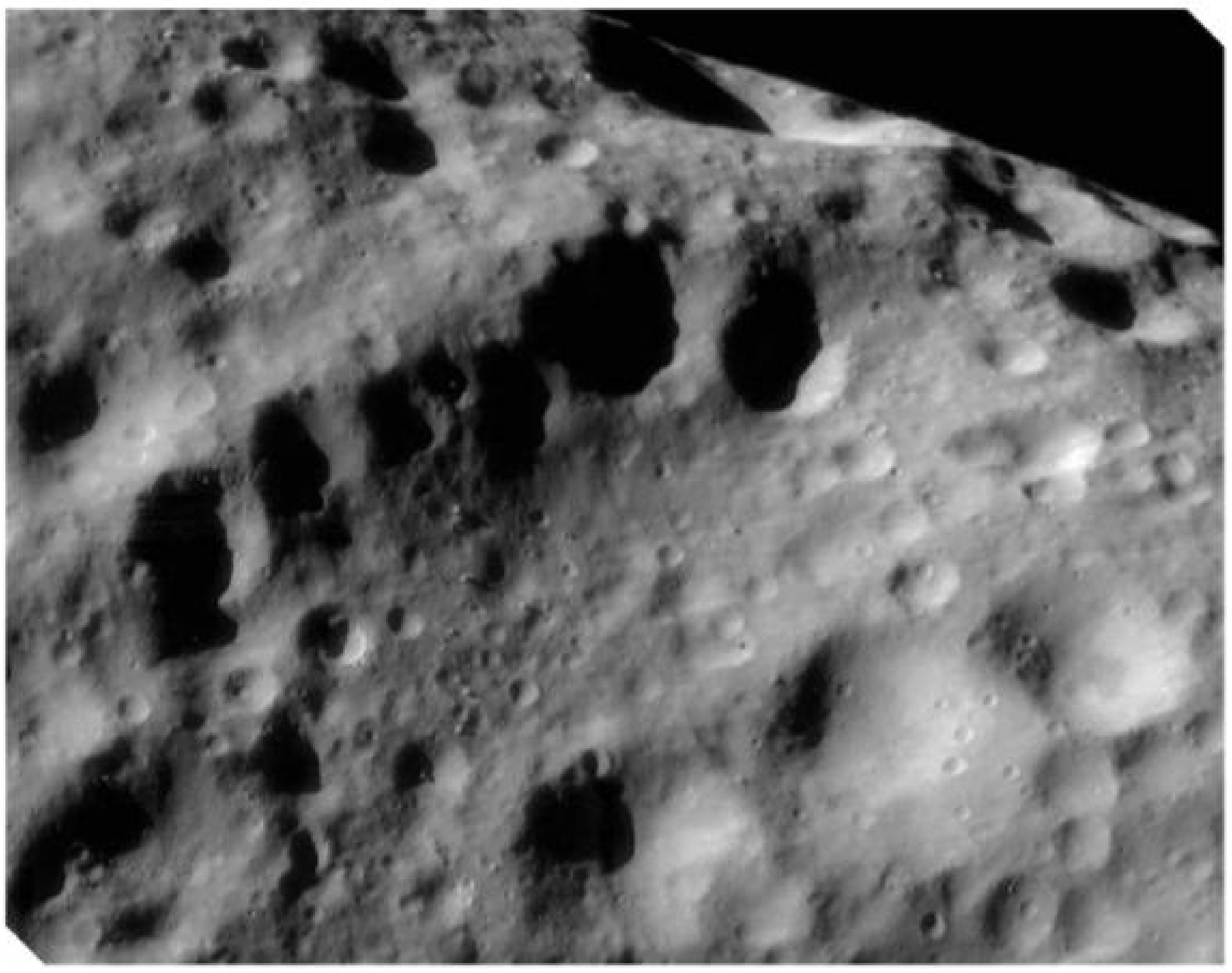
Shaoni Bhattacharya interviews Hannah Susorney

Q&A WITH AN ASTEROID MAPPER

By analysing the surface features of asteroids we can gain vital information about their interiors – and help to deflect them from colliding with Earth

What is the EROS project?
It stands for 'ExploRing the surface slopes Of aSteroids'. I am trying to understand asteroid interiors by using observations of their surfaces. I have been using data from spacecraft and the Arecibo Telescope to see if we can use models of asteroid shapes to do that.

How can an understanding of an asteroid's shape tell us about its interior?
For starters, it could tell us about the surface processes. For example, if you are walking around on Earth and you go to Cheddar Gorge in Somerset you will find it is really steep. The reason is because the rock is intact and it won't flow down. In contrast, when you build a sand castle on a beach, you can't make it very steep because the loose sand granules will flow down. So we are looking at the slopes on asteroids to try and understand how intact they are, which also avoids having to send a mission to every asteroid to investigate. We can understand a lot about how high or big slopes are on an asteroid remotely.



▲ A close-up of the asteroid Eros, as taken by NEAR Shoemaker in 2000. Scientists are learning about the interior composition of these space rocks by looking at surface features such as slopes

NASA/NEAR PROJECT (JHU/APL)

Where do you get the data to estimate the shape of an asteroid?
We have lots of shape models of asteroids and we have been looking at the slopes of the ones that we have visited with spacecraft, where we know a lot about the surface and the interior. Next, we try to understand how we can compare that information to other space rocks that we don't know. For example, asteroids that have smoother surfaces are more like Itokawa, which we think has lots of holes in it and a low density. And asteroids with higher surface slopes are more like Eros, visited by the NEAR Shoemaker spacecraft, which has a more intact interior.

How do you use the data to understand asteroids?
We mainly take shape models that have already been made – those that come from spacecraft observations tend to be the highest resolution. We can then take shape models from Arecibo Telescope data – we have a tool that can take the internal density and look at how that affects the surface slope.

For the asteroids we've visited we have very well-constrained data about densities. You can see how the asteroid's gravity deflects the spacecraft slightly, so you can calculate its mass, and combining the mass and volume will give the density. But there are hundreds of thousands of asteroids, so how do we say something about these with lower resolution data? That's really the goal.

How is Arecibo data used?
The Arecibo Telescope would send out radio waves, which bounce off the surface of an asteroid and come back. You have a computer model that starts with a basic asteroid shape, and it keeps changing the shape to try to match the observations. For example, we have a good shape model of asteroid Bennu from observations by the OSIRIS-REx mission. When we compared the radar shape model with this we found it matched quite well. We also have data sets from spacecraft observations of Itokawa, Ryugu and Eros.

What were the main challenges of this project?
Asteroids range in size from being hundreds of metres across to say, Eros, which has a diameter of 34km. So how do you compare apples and oranges? Is there some sort of dimensionless thing we can look at? A slope is quite good for that because if you look at the same baseline, you're comparing apples with apples.

How might your models be useful for deflecting hazardous asteroids away from Earth?
It's a low cost, rapid way of understanding asteroid interiors. Internal structure is important when you run into something, because of its momentum and also how it reacts. That's one of the huge unknowns with the DART mission – how does a bag of dirt interact to being hit with something? Composition is probably the most important information: how big a rocket do you need to send? You can model it all but if you don't know what the asteroid is really like, you won't know how the asteroid will react during a collision.

Dr Hannah Susorney is a planetary scientist and Marie Skłodowska-Curie Research Fellow at the University of Bristol

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1.7MP - £1436
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Explore Scientifc 127mm Apo - FROM £1429
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PRECISION MOTION CONTROLLER
Explore Scientifc 50mm & 60mm guidescopes - FROM £167
NEW!
Introducing the new Explore Scientifc 70, 82, 100 and 120mm Astrobinoculars + U-Mount. Exceptional quality & value for money. Starting from £989
NEW!
Introducing the Bresser Bino Viewer Deluxe 1.25" includes zero-length/ mag transfer lens - no in focus, or Barlow needed. Can be used with all types of telescopes, Newtonians included!
Get organised with the Explore Scientifc Eyepiece & Accessory Bag- £28
National Geographic 114/500 Tabletop Dob -£129
NEW!
Check out the new Lunt LS40 starter Hydrogen Alpha Solarscope - £866.80
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Vixen SXP2-AX103S Telescope Complete Set £7322.30
NEW!
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All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

Enjoy bright Jupiter and Venus, and look out for two meteor showers, the Phoenicids and Puppid-Velids

When to use this chart

1 Dec at 00:00 AEDT (13:00 UT)
15 Dec at 23:00 AEDT (12:00 UT)
30 Dec at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

DECEMBER HIGHLIGHTS

Two meteor showers reach their peak this month. The Phoenicids is active from 28 November to 9 December. Although inconsistent over the years, with its radiant culminating in the early evening and close to new Moon, its peak night of the 2nd should provide many dark hours.

The Puppid-Velids are visible in the first two weeks of December. They peak on the night of the 7th and with a four-day-old Moon, the morning skies will be dark with the radiant high in the south.

STARS AND CONSTELLATIONS

Taurus, the Bull is home to the two closest open star clusters. One is the Pleiades, M45, looking compact with its 'seven sisters' (stars) covering around 1° across. The other is the more dispersed Hyades – the V-shaped bovine's face – around 4° across. As the path of the Sun and all the planets passes between these two clusters they form what's known as the 'Golden Gate of the Ecliptic' asterism. The Moon is an exception – with a high inclination it can go around.

THE PLANETS

The beacons of Venus and Jupiter dominate the western evening sky, with Jupiter the higher of the two. Between them is Saturn, looking more like a 1st magnitude star. Venus remains visible after twilight for the first three weeks of December, before departing the evening sky as it nears conjunction.

Neptune sets around midnight mid-month, followed by Uranus two hours later. Mornings see the return of Mars, as it climbs out of the dawn glow.

DEEP-SKY OBJECTS

This month we visit Andromeda, the Chained Princess. Although close to the northern horizon, the following objects attain a similar altitude to the Andromeda Galaxy and can be viewed as twilight ends. The double star Gamma (γ) Andromedae (RA 02h 03.9m, dec. +42° 20'), at 2nd magnitude is visible to the unaided eye. A telescope shows two components of mag. +2.3 and +5.0, coloured yellow and blue and separated by 9.5 arcseconds.

A stroll 5° north of Gamma Andromedae finds the mag. +5.7 open star cluster NGC 752 (RA 01h 57.7m, dec +37° 47'). It's visible in binoculars, as is the binocular double star 56 Andromedae on the southwestern edge – a pair of 6th magnitude stars, 3 arcminutes apart.

NGC 752 is best observed in wide fields, being 1° across and consisting of about 60 well-scattered stars arranged in short curved lines.

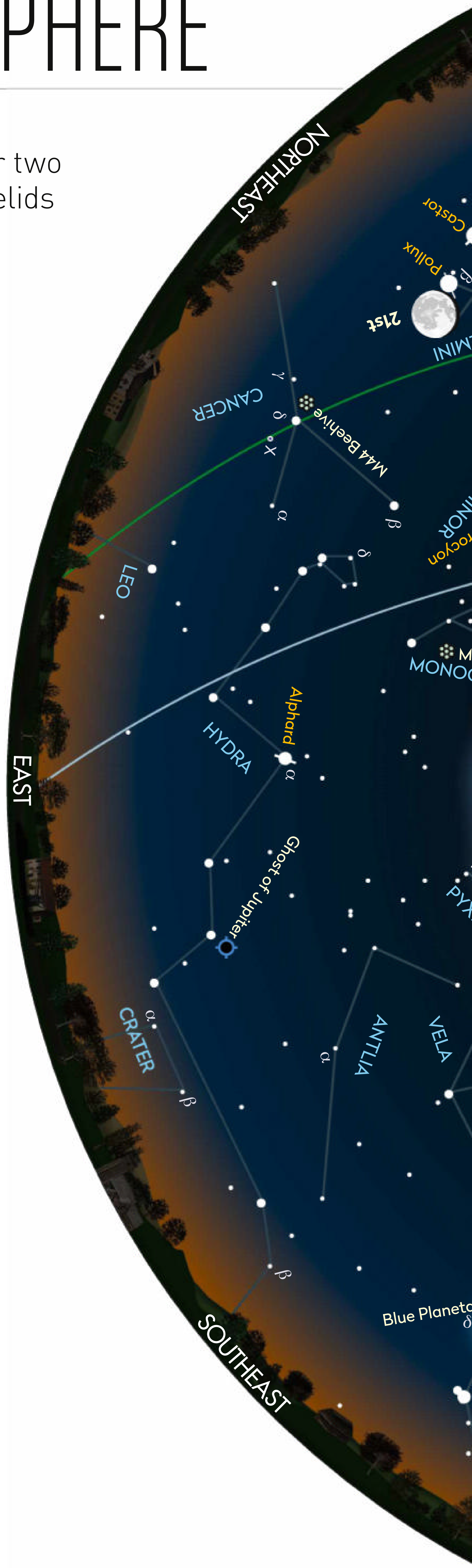

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Algol
M34
Almach
NGC 752
ANDROMEDA
California Nebula
M36
M37
M38
M35
TRIANGULUM
M33
18th
Pleiades
Hamal
ARIES
PISCES
PEGASUS
Great Square of Pegasus
Aldebaran
Hyades
Ecliptic
15th
Uranus
ORION
Betelgeuse
TAURUS
Menkar
Alrescha
M78
Rosette
M43
M42
Rigel
Celestial Equator
Mira
CETUS
12th
Circlet
Winter Triangle
Sirius
M50
CANIS MAJOR
MONOCEROS
M47
M41
LEPUS
ERIDANUS
Neptune
PUPPIS
COLUMBA
CAELUM
HOROLOGIUM
NGC 253
Deneb Kaitos
AQUARIUS
Canopus
Puppid-Velid Radiant 7 Dec
CARINA
PICTOR
DORADO
RETICULUM
NGC 300
PHOENIX
SCULPTOR
Fomalhaut
9th
Helix
Achernar
Phoenicids Radiant 2 Dec
Tarantula Nebula
LMC
NGC 1466
SMC
NGC 362
PISCIS AUSTRINUS
VOLANS
MENSA
South Celestial Pole
HYDRUS
47 Tucanae
TUCANA
GRUS
Gem Cluster
CHAMAELEON
Southern Pleiades
OCTANS
INDUS
PAVO
Acrux
MUSCA
Coal Sack
CRUX
Jewel Box
APUS
CENTAURUS
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